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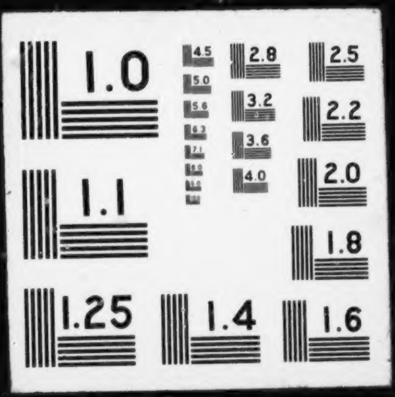
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1. Report No.

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3. Accession No.
W 72-04260

4. Title
WATER QUALITY CONTROL THROUGH FLOW AUGMENTATION,

5. Report Date

6.

8. Performing Organization Report No.

7. Author(s)
Baker, David B and Kramer, Jack W

10. Project No. EPA
Program 16080DF001/7

9. Organization
Heidelberg College, Tiffin, Ohio, Biology Dept

11. Contract/Grant No.

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes Environmental Protection Agency, Water Quality Office, Water Pollution Control Research Series, ~~16080DFO~~, January 1971. 156 p. 27 fig, 8 tab, 14 ref, 12 append

16. Abstract

A 60-mile section of the Sandusky River, Ohio, was investigated to evaluate the relationship between the volume and the quality of flowing water. The content of fluoride, calcium, magnesium, and sodium were directly and those of total and soluble phosphorus indirectly related to the flow volume. No correlation was observed between the flow and concentration of either potassium or nitrates. Oxygen content was high at an abundant flow, but showed considerable variation, being influenced by respiration of algae. The study suggested that an increased current velocity reduces the density of algal populations. (Wilde-Wisconsin)

17a. Descriptors *Water quality control, *Flow augmentation, Water quality, Reservoirs, Water pollution sources, Algae, River flow, Phosphorus, Nitrates, Potassium, Dissolved oxygen, Forecasting, Fluorides, Ohio

17b. Identifiers Sandusky River (Ohio)

SOD # EP2.10:16080DF001/71
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17c. COWRR Field & Group 05G

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

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WATER QUALITY CONTROL THROUGH FLOW AUGMENTATION

by

Biology Department
Heidelberg College
Tiffin, Ohio

for the

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE

Program 16080 DFO
January, 1971

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ABSTRACT

To evaluate effects of flow augmentation from upground reservoirs on water quality, studies of the relationship between water quality and flow volume were undertaken in a 60-mile section of the Sandusky River in North Central Ohio.

Chemicals such as calcium, magnesium, fluoride and sodium, which enter the river primarily as components of ground and surface runoff water, had lower concentrations at high flow volumes and higher concentrations during low flow periods. In contrast, for most river sections concentrations of total phosphorus and soluble orthophosphorus were lower during low flow periods and increased as flow volume increased. These increases in phosphorus concentration were probably due to agricultural surface runoff. Immediately downstream from sewage treatment plants, orthophosphorus concentrations did increase with decreasing river flow. During most of the study period the total phosphorus flux at the downstream station was much less than the total upstream input from sewage treatment plants. Nitrate and potassium concentrations were variable and showed no correlation with river flow.

Oxygen concentrations were near saturation at medium and high flows but varied widely above and below saturation at low flows. It was concluded that in most river sections algal respiration rather than B.O.D. was responsible for low D.O. values. It is predicted that flow augmentation will significantly reduce algal growth in the stream. This effect would probably arise from increased flow velocity rather than dilution of algal nutrients.

This report was submitted in fulfillment of Grant 16080 DFO under the sponsorship of the Environmental Protection Agency.

Keywords: Water Quality, Water Analysis, Flow Augmentation, Water Management, Reservoirs, Nutrients, River flow, Water Pollution Sources, Sandusky River, North Central Ohio.

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SECTION I

SUMMARY AND CONCLUSIONS

In order to evaluate the effects of flow augmentation from upground reservoirs, a detailed study of the relationship between river flow volume and the concentrations of a variety of chemicals was undertaken on a 60-mile section of the Sandusky River. Although considerable variation in river flow did occur during the study periods, the flows did not drop to the levels where flow augmentation would have been implemented. Using the patterns of relationships between concentration and flow volume and considerations of input sources, predictions were made for conditions during severe low flow periods. A second set of predictions was then made with respect to the effects of flow augmentation. These observations and predictions are summarized below.

1) The concentrations of calcium, magnesium and sodium tend to increase as flow volume decreases. There are, however, considerable variations in concentrations at low flows. Extrapolation of concentration-flow curves suggests that during severe low flows the concentrations of these chemicals would fall in the same range as those observed during the lowest flow periods of this study. Assuming that the reservoir is filled during high flow periods, it should have relatively low concentrations of these chemicals; and, consequently, as the amount of flow augmentation increases, the concentrations of calcium, magnesium and sodium should decrease.

2) During periods of low flow, the domestic loading of fluoride represents a large fraction of the total fluoride flux in the river. As flow volume decreases, the concentration of fluoride increases. At high flows the fluoride concentrations are low but the total flux increases considerably, indicating the presence of natural fluorides in the river. Under severe low flows the fluoride concentration would increase to higher levels than those observed in this study due to the relatively constant input from domestic sources. During flow augmentation the fluoride concentrations would be similar to those of the lowest flows observed in this study.

3) In most sections of the river the concentration of total phosphorus and soluble orthophosphorus decreased as flow volume decreased. The higher concentrations at higher flows were probably due to the entrance of phosphorus bound to silt particles accompanying agricultural surface runoff. At sections immediately below sewage treatment plants, orthophosphorus concentrations did increase as stream flow decreased. Under severe low flow conditions, in most sections of the river, the total phosphorus and soluble orthophosphorus would either remain in the same range as observed in low flows during the study or would perhaps decrease still further. During severe low flows immediately below treatment plants, the orthophosphorus concentration would increase even higher than observed in this study. Assuming that the reservoir water has low phosphate concentrations, flow augmentation at sites immediately downstream from treatment plants would have phosphorus concentrations similar to those observed during low flows in this study. For most sections of the river, slight dilutions of phosphorus would occur during augmentation, giving these periods the lowest phosphorus concentrations of the year.

4) The concentrations of potassium and nitrate-nitrogen were extremely variable and showed no correlation with river flow. It is anticipated that this same variability would persist during both severe low flow conditions and flow augmentation.

5) In most sections of the river the biochemical oxygen demand (B.O.D.) was fairly low and showed little correlation with flow. At sites downstream from treatment plants it is anticipated that B.O.D. values would increase with decreasing flows. For most sections of the river the B.O.D. values are at their "natural" levels and would not increase with further decreases in flow volume unless associated with algal blooms. Flow augmentation would have little direct effect on B.O.D. values in most sections of the river. Below treatment plants flow augmentation would prevent B.O.D. values from increasing to levels higher than those observed during the low flows of this study.

6) The concentration of dissolved oxygen (D.O.) was near saturation at medium and high flows but varied widely both above and

below saturation during low flows. During severe low flows the variations in D.O. would probably be even greater, giving rise to numerous D.O. values below the minimum acceptable values according to state water quality standards. These low D.O. values are probably caused by algal respiration. During severe low flows, increased algal growth could be anticipated based primarily on the longer time periods available for algal growth during low flows. Flow augmentation could significantly reduce algal growth primarily through decreasing the travel time in the stream and secondarily through dilution of nutrients.

7) Examination of the fluxes of materials in the river indicated that the most significant loadings occur during periods of high flow. This is especially so for chemicals whose concentrations increase with increasing flow, such as phosphorus. On most occasions the phosphorus fluxes at the downstream station were considerably less than the input from domestic sewage treatment plants. It is not known to what extent the phosphorus that leaves the water during low and medium flows re-enters the water and contributes to the high fluxes during high flows.

SECTION II

RECOMMENDATIONS

To date the studies have provided a basis for concrete predictions of conditions during both severe low flows and flow augmentation. Significant improvements in water quality arising from flow augmentation are anticipated.

The construction of numerous upground reservoirs in northwest Ohio does represent a considerable alteration of the environment. The total effects of flow augmentation from these reservoirs on river ecosystems are difficult to predict and will require detailed and specific studies if these effects are to be understood. It is recommended that studies such as the one which we have initiated here be considered for additional support.

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SECTION III

INTRODUCTION

Project Background

In 1965 the Ohio Water Commission authorized the preparation of a comprehensive water resource development plan for Northwestern Ohio. The objectives of this study were to anticipate the water resource needs for the next 40 years that would give "maximum support to the growth and development of the region" and to present "programs for the total management of water so that the greatest economic and social benefits may be realized." The results of this study were published in January, 1967 as The Northwest Ohio Water Development Plan.[1]

The above plan calls for the construction of a system of 37 multipurpose, upground reservoirs as the key facilities for water resource development in this region. These reservoirs will be located in the upper reaches of the mainstreams and will be filled during periods of high flow. The water stored within the reservoirs will then be used for public, industrial and agricultural water supplies and for recreational purposes. In addition, during periods of low natural runoff, water from these reservoirs will be used to sustain certain minimum stream flows, thereby insuring adequate water supplies to downstream users and improving water quality through flow augmentation effects.

Although it is anticipated that the proposed sustained flow program will result in significant improvement in water quality, actual documentation of such effects is lacking. Also, management guidelines for obtaining maximum benefits of flow augmentation from upground reservoirs are not available. Consequently a demonstration study designed to directly evaluate the effects of flow augmentation from an upground reservoir on one of the streams of Northwest Ohio seemed appropriate during the early stages of implementation of the plan.

In 1968 Heidelberg College, in collaboration with the Ohio Department of Natural Resources, proposed to undertake such a study

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on the Sandusky River. Construction of a state owned and operated upground reservoir in the vicinity of the Killdeer Plains Wildlife Area was scheduled to begin that fall. This reservoir will have a total capacity of 2,018 million gallons of which 1,778 million gallons are designated for sustained stream flow. Excess flow in Tymochtee Creek, a tributary of the Sandusky River, will be stored in the reservoir. In all, some 75 miles of stream channel along Tymochtee Creek and the Sandusky will be affected by releases from this reservoir. This reservoir will be entirely under the jurisdiction of the Ohio Department of Natural Resources and consequently will be ideally suited for experimentation on the effects of various levels of sustained stream flow on water quality.

In early January, 1969, Heidelberg College received a grant from the Federal Water Pollution Control Administration to initiate the study. The project timetable called for a 3-year study and anticipated that the reservoir would be completed and ready for use during the last two years of the project. In view of delays in the onset of construction of the reservoir, the F.W.P.C.A. did not approve the application for support for the second year of the study. This report will therefore summarize the work which was accomplished during the first year of a proposed 3-year project, and a subsequent 6-month period for bringing the project to an orderly conclusion. Although support was received for 18 months, the period encompassed only one late summer-early fall period when low stream flows are most prevalent.

Much of the work during the first year of the study amounted to "tooling up" for the intensive water quality surveillance program which was to be the basis for the project. This tooling up included designing, constructing, and outfitting a water analysis laboratory. Many of these preparations were completed during the first six months of the project so that an intensive water quality surveillance program was underway during the summer and fall of 1969. This report will consist primarily of a presentation and analysis of the data collected during this period.

Since the state has subsequently released funds for the construction of the reservoir and construction is currently underway, it is hoped that the original project can be resumed. Completion of the reservoir is scheduled for the fall of 1971 and the first possibilities for flow augmentation experiments will be during the low flow periods of 1972.

The work which was accomplished during the first year was not intended to constitute a complete study in itself. Instead, it was mainly intended to provide background data for subsequent evaluation of flow augmentation effects. Since the work can best be understood in terms of the overall project, the original study plan for the 3-year period will be summarized in the next section.

Original Study Plan

As sources of flow augmentation water, the upground reservoirs proposed in The Northwest Ohio Water Development Plan differ in two important ways from the more typical on-stream reservoirs. First, since water is pumped into these reservoirs, it is possible to select the best quality water for storage. Secondly, the volume of water stored within the upground reservoirs and available for flow augmentation is typically smaller than that available from on-stream reservoirs. In northwestern Ohio the proposed upground reservoirs have been designed to maintain stream flows at levels which were equalled or exceeded 80% of the time based on adjusted 1921-1945 flow duration values. In other words, the lowest 20% of the flows will be eliminated. Generally speaking, upground reservoirs will provide a relatively low volume of high quality water for augmentation purposes.

There are two principal ways in which flow augmentation can affect water quality. The first of these is through dilution effects accompanying the increased flow. The augmentation water should have a higher D.O. content, a lower B.O.D., lower nutrient levels, and lower concentrations of toxic chemicals than agricultural, domestic or industrial effluents entering the stream. Consequently, the greater the amount of augmentation water relative to waste effluents, the better the water quality should be. Effects of augmentation on stream water temperature could also be important and can be considered as dilution effects.

The second way which flow augmentation can affect water quality is through physical effects accompanying increased flow. These include increases in flow velocity (decreases in time of passage), altered rates of gas exchange and altered expanses of riffle conditions in the stream.

Through both dilution effects and physical effects, the addition of high quality water from upground reservoirs is bound to bring about a host of small changes in conditions within the river. One objective of this study was to document the "small changes" which will accompany the sustained flow program. Of greater importance, however, is the way the river system as a whole responds to the set of small changes resulting from sustained flow. A river constitutes a complex ecosystem and it is very difficult to predict the effects of the numerous small changes which will accompany flow augmentation.

As evidence of responses of the "river system as a whole," the study was to include measurements of as wide a variety of biological components as possible. In particular, the effects of sustained flow on algal bloom development, benthic organisms, fish populations and bacterial populations were to be investigated. Most flow augmentation studies heretofore have concentrated on the effects of augmentation on the oxygen sag characteristics downstream from sources of organic loading such as sewage treatment plants.

A major complication in determining both the small changes and the ecosystem level responses to sustained flow is that a wide variety of other developments will simultaneously be occurring within the basin. Other pollution abatement projects, changing agricultural practices, increased population, etc., will all be contributing their own small changes to the river and the river as a whole will be responding to these changes. Untangling cause-and-effect relationships so that the effects of flow augmentation can be separated from other factors will be a difficult task.

The effort to isolate and evaluate the effects of flow augmentation was to consist of combining the following three approaches:

1) An intensive water quality surveillance program would be established for the 75-mile section of the river which will be affected by flow augmentation. The surveillance would be "intensive" in three senses. We would measure as many different chemical, biological and physical parameters as possible. We would collect samples from as many separate locations within the river section as possible. We would collect samples as frequently as possible. An important initial product of this program would be a close look at the way in which a wide variety of water quality parameters vary with flow volume. The specific analyses to be included, sampling locations and sampling frequency would be adjusted during the course of the project as evaluation of the data proceeded.

2) The intensive surveillance program would be in effect during the times of the year when low flows are expected (July, August, September and October). Less intensive surveillance would be carried out on a year-round basis. Measurements obtained during low flow periods prior to the completion of the reservoir would be used as a baseline for comparing conditions present during periods of flow augmentation. After completion of the reservoir, a variety of specific flow augmentation experiments would be carried out to help isolate the effects of varying flow volumes on water quality.

3) A systems analysis approach would be used in the data analysis. The river section would be treated as an "open system" and material fluxes into, through and out of the system would be analyzed. This "balance sheet" approach would help to isolate the effects of augmentation from other effects.

The overall project was to involve the close cooperation of the Ohio Department of Natural Resources, the U.S. Geological Survey and Heidelberg College staff. Four continuously recording water quality monitors have been installed within the study area by the Ohio Department of Natural Resources and the U.S. Geological Survey. These provide continuous measurements of dissolved oxygen, pH, temperature and conductivity. Four continuously recording stream gages managed by the U.S. Geological Survey are also present in the study area. Loading data from the sewage treatment plants as well as water chemistry data from two U.S. Geological Survey sampling stations were to have been incorporated into the study. Measurements of fish populations were to have been done by the Wildlife Division of the State Department of Natural Resources. The flow augmentation experiments using water from the Killdeer Reservoir were to consist of the joint efforts of Heidelberg College and the Ohio Department of Natural Resources.

SECTION IV

THE STUDY AREA

The Sandusky River is one of the north central Ohio tributaries to Lake Erie (Figure 1). The river is about 115 miles long and drains an area of 1421 square miles, most of which is agricultural land. The profile of the river is extremely variable, ranging from a drop of less than 2 feet per mile in many areas to other places, such as below Tiffin, where the fall is 25 feet per mile.

The upper 55% of the basin is in the Till Plain which is traversed by a low east-west moraine south of Upper Sandusky and another south of Tiffin. The lower 45% of the basin is in the Lake Plains subprovince. The bedrock at or near the surface consists of dolomite, limestone, and shale of Silurian and Devonian age. These formations are relatively dense and ground water storage is not great. The overburden of glacial drift and lacustrine deposits are generally thin and relatively impermeable. In the southern part of the basin near Upper Sandusky, Bucyrus and Crestline, the drift thickens and is more permeable in the areas of morainal deposits.

The soils of the Sandusky Basin are variable. In the lake plain area, the very poorly drained Hoytville silty clay loam and clay are dominant. In the till plains the soils are derived from moderately fine textured Wisconsin glacial till. In the western part of the till plain the soils have developed over limestone while in the eastern part they have developed over a sandstone-shale area. Throughout the basin, ground water contribution to stream flow is small and sustained flow is low.

In 1966 the population of the basin was 191,000. The major towns along the Sandusky River include Crestline, Bucyrus, Upper Sandusky, Tiffin and Fremont. All of these towns currently provide secondary waste treatment. These towns, as well as many smaller communities within the basin, currently have a variety of projects underway which should improve water quality. These projects include expansion of secondary treatment plants,

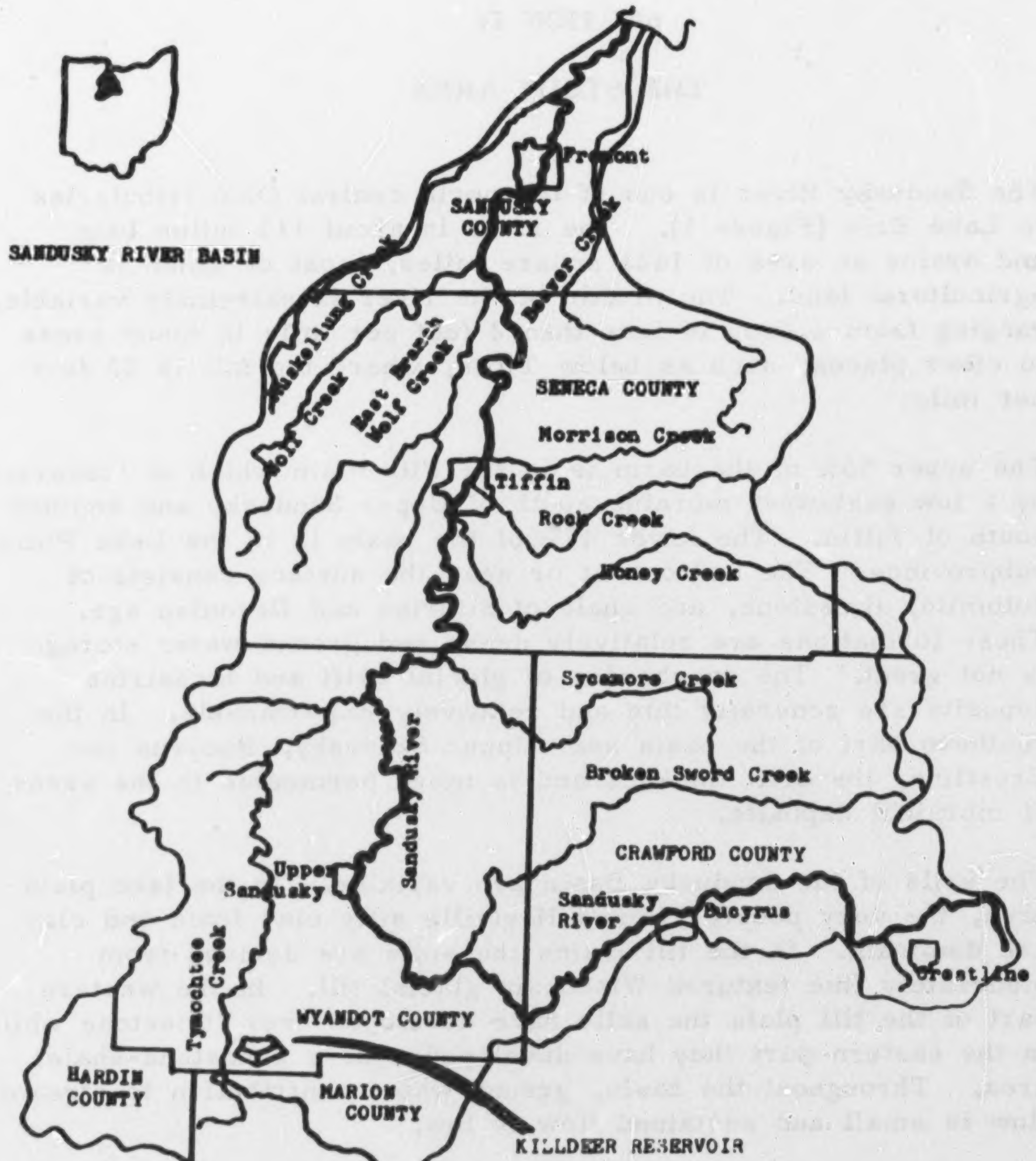

SANDUSKY RIVER BASIN
Fremont
SANDUSKY COUNTY
Muskellunge Creek
Beaver Creek
East Branch Wolf Creek
Wolf Creek
SENECA COUNTY
Morrison Creek
Tiffin
Rock Creek
Honey Creek
Sycamore Creek
Broken Sword Creek
Sandusky River
CRAWFORD COUNTY
Upper Sandusky
Sandusky River
Bucyrus
Crestline
Tymochtee Creek
WYANDOT COUNTY
HARDIN COUNTY
MARION COUNTY
KILLDEER RESERVOIR

Figure 1. The Sandusky River Basin

construction of lagoons, improvement of sewage collection systems and separation of combined sewers.

At present, water quality in the Sandusky River is impaired by pollutants from both domestic and agricultural sources and to a lesser extent by industrial effluents. During the late summer and fall, depressed oxygen levels are common immediately downstream from Bucyrus and Fremont. In the case of Bucyrus, most of the stream flow consists of the treatment plant effluent during low flow periods. In Fremont, a combination of raw sewage from a faulty collection system, wastes from food processing plants and possibly algal blooms all contribute to a lowering of the oxygen levels.

Perhaps the most visible of the pollutants entering the Sandusky River is the silt which accompanies surface runoff from farm land. Although the basin is fairly flat, the relative impermeability of the soils coupled with their fine texture result in serious sheet erosion. During much of the year the Sandusky River is brown in color. Large quantities of phosphates are bound to the silt particles. These phosphates, along with nitrates of agricultural origin and nutrients passing through the sewage treatment plants, maintain high nutrient levels in the river and contribute to the nutrient input into Lake Erie.

Although the Sandusky River does show many of the attributes of a polluted river, it also has considerable potential for recreational development. In January, 1970, a 60-mile section of the river was designated as an Ohio State Scenic River. As such, canoe routes, hiking trails, and overnight camping areas are being planned for the river. Measurements taken as part of this study indicate that the fecal coliform bacterial counts throughout the area designated as a scenic river exceed the recommended levels for safe recreational usage. (See Section XI).

The Northwest Ohio Water Development Plan calls for the eventual construction of 6 upground reservoirs in the Sandusky Basin. With respect to flow augmentation, the most important of these reservoirs will be the Killdeer Reservoir located in a state wildlife area in Wyandot County.

More detailed information on the geology, physiography, soils and geography of the Sandusky River Basin can be found in The Northwest Ohio Water Development Plan,[1] the Scenic River Study: Sandusky River,[2] and Flow Duration of Ohio Streams.[3]

SECTION V

METHODS

Sampling Procedures

The sampling locations are shown in Figure 2. The designations for the sampling locations (S-22, W-02, T-20, etc.) were arrived at by using the first initial of the stream or tributary coupled with a number that reflects a numerical sequence of bridges along the stream beginning at Lake Erie for Sandusky River locations or at the Sandusky River for tributary locations. All of the sampling was done from bridges. The exact location of each bridge used as a sampling site, along with the corresponding mileage point along the river is listed in Table I.

The study area was bounded by the U.S.G.S. stream gages located at S-52 below Upper Sandusky, at T-20 near Crawford on Tymochtee Creek, and at S-10 upstream from Fremont. Additional sampling locations on the Sandusky River were established at the bridges above and below the point where Tymochtee Creek enters the Sandusky River (S-40 and S-38), at the U.S.G.S. stream gage near Mexico (S-26), near the water intake for Tiffin (S-24) and above and below the entrance of the Tiffin Sewage Plant effluent (S-22 and S-20). The remainder of the collection sites are located on the major tributaries which enter the river in the study area. These include Honey Creek (H-20), Rock Creek (RC) and Wolf Creek (W-02). A typical collection trip, in which all of the stations were visited, involved travelling approximately 100 miles and required 4 hours. Sampling was done during the morning hours and the samples were returned to the lab before noon for the beginning of analyses. The sampling route was reversed on successive days.

The water samples were collected by lowering a plastic bucket from the bridge into the section of the river which was judged to have maximum flow. Tests indicated that at all of the sampling locations, mixing was sufficient for this procedure to give representative samples. Oxygen and temperature measurements

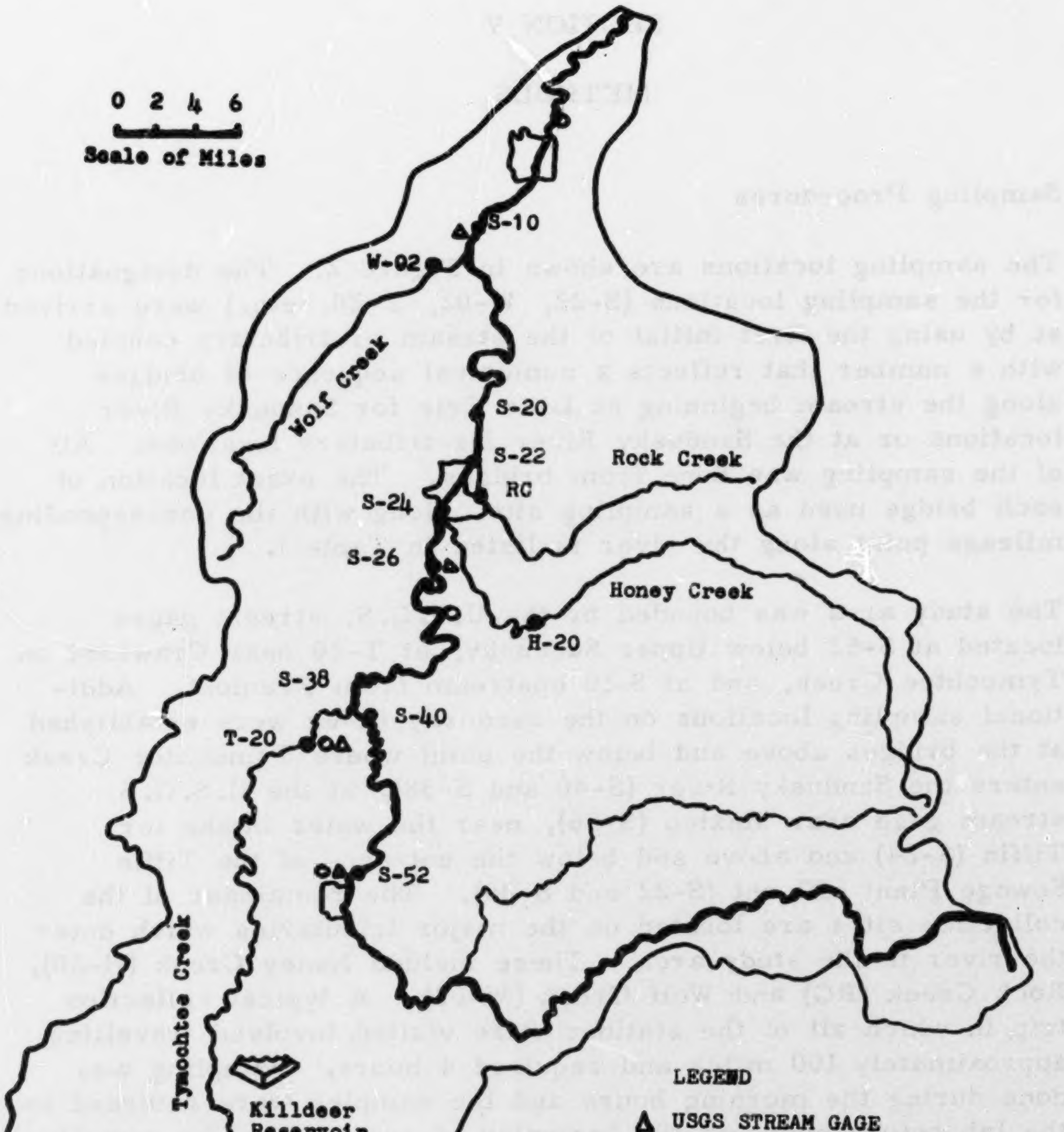

0 2 4 6
Scale of Miles
S-10
W-02
Wolf Creek
S-20
S-22
Rock Creek
RC
S-24
S-26
Honey Creek
H-20
S-38
S-40
T-20
S-52
Tymochtee Creek
Killdeer Reservoir
LEGEND
▲ USGS STREAM GAGE
○ CHEMICAL WATER QUALITY MONITOR
● SAMPLING LOCATION

Figure 2. Location of Sampling Stations, U.S.G.S. Stream Gages and Chemical Monitors

TABLE I. Road Designations and Mileage Points for Sampling Stations

Station Number	River Miles from Lake Erie	Bridge	Road
S-10	19.55	Tyndal (USGS)	Rice Rd., Sandusky C.R. 221
S-20	35.75	Township Line	Seneca Co. Rd. 38
S-22	38.55	State Hospital	Huss Street, Tiffin
S-24	41.15		Ella Street, Tiffin
S-26	46.08	Scott (USGS)	Seneca Co. Rd. 90
S-38	59.5		Wyandot Co. Rd. 9
S-40	61.0		State Route 103
S-52	76.7	(USGS Gage Station)	Wyandot Co. Rd. 121
W-2			State Route 53
H-20			State Route 100 at Melmore
T-20		(USGS Gage Station)	State Route 199 at Crawford

S - Sandusky River
W - Wolf Creek
H - Honey Creek
T - Tymochtee Creek

were taken on water in the bucket using an oxygen meter. Then 300 ml of water were poured into a sterilized glass bottle for bacterial analysis, 500 ml of water were added to a plastic bottle containing 5 ml of concentrated nitric acid for atomic absorption analysis, and 2 liters of water were transferred to a plastic bottle for the remainder of the analyses. Since the analyses were usually started within 6 hours of sample collection, neither chemicals nor cooling was used to preserve the 2 liter samples.

At the time of sample collection the river stage was determined by using a U.S.G.S. wire weight gage (stations S-10, S-26, S-52, T-20 and H-20) or by measuring the distance to the water surface from a fixed reference point on the bridge (remainder of stations).

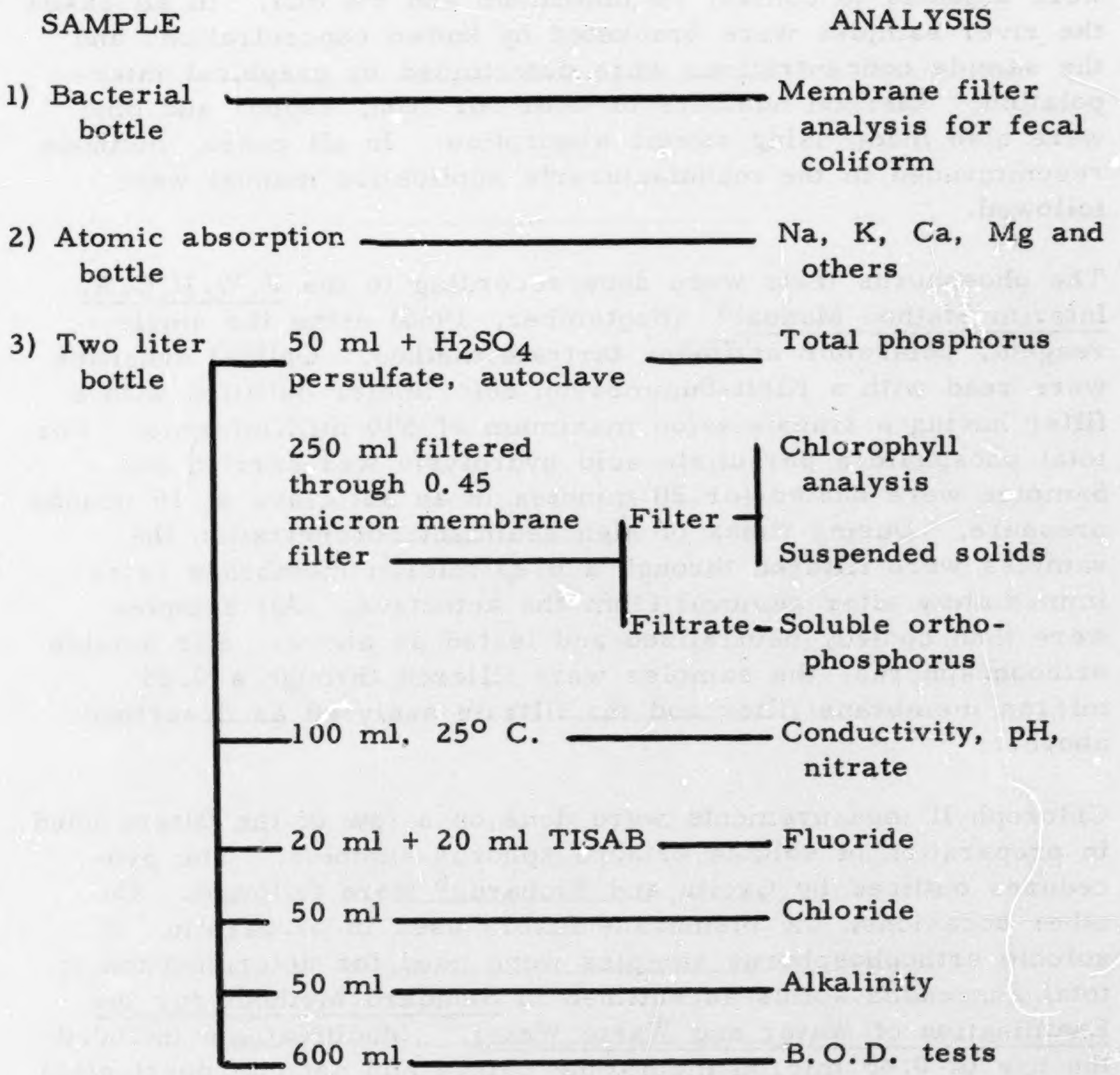
Sampling Frequency

During July and August, 1969, samples were collected five times per week at each of the sampling stations. During September and October, sample collections averaged three to four times per week. From November, 1969, through May, 1970, samples were collected once per week except when heavy ice conditions were present. During times of heavy ice conditions, sampling was either discontinued or confined to gage station sites.

Laboratory Procedures

Figure 3 contains a flow sheet which outlines the procedures used in the analysis of river samples. Bacterial analyses were limited to tests for fecal coliform bacteria. The membrane filter procedure was used as outlined in the Millipore Corporation Application Data Manual 40, "Techniques for Microbiological Analysis."[4] For each sample, two volumes of river water were tested and only those plates with counts falling in the range of 20 to 200 colonies per filter were considered valid.

The analyses for calcium, magnesium, sodium and potassium were done by atomic absorption using a Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer outfitted with a recorder readout. For the analyses of calcium and magnesium the samples


SAMPLE
ANALYSIS
1) Bacterial bottle
Membrane filter analysis for fecal coliform
2) Atomic absorption bottle
Na, K, Ca, Mg and others
3) Two liter bottle
50 ml + H_2SO_4 persulfate, autoclave
Total phosphorus
250 ml filtered through 0.45 micron membrane filter
Filter
Chlorophyll analysis
Suspended solids
Filtrate
Soluble orthophosphorus
100 ml, 25° C.
Conductivity, pH, nitrate
20 ml + 20 ml TISAB
Fluoride
50 ml
Chloride
50 ml
Alkalinity
600 ml
B.O.D. tests

(Field measurements included dissolved oxygen, temperature, time of collection and river stage.)

Figure 3. Flow Sheet for Laboratory Analyses

were adjusted to contain 1% lanthanum and 5% HCl. In all cases the river samples were bracketed by known concentrations and the sample concentrations were determined by graphical interpolation. Limited numbers of tests for iron, copper and zinc were also made using atomic absorption. In all cases, methods recommended in the manufacturer's application manual were followed.

The phosphorus tests were done according to the F.W.P.C.A. Interim Method Manual[5] (September, 1968) using the single reagent, potassium antimony tartrate method. Optical densities were read with a Klett-Summerson colorimeter outfitted with a filter having a transmission maximum of 690 millimicrons. For total phosphate a persulfate acid hydrolysis was carried out. Samples were heated for 20 minutes in an autoclave at 15 pounds pressure. During times of high sediment concentration the samples were filtered through a 0.45 micron membrane filter immediately after removal from the autoclave. All samples were then cooled, neutralized and tested as above. For soluble orthophosphorus, the samples were filtered through a 0.45 micron membrane filter and the filtrate analyzed as described above.

Chlorophyll measurements were done on a few of the filters used in preparation of soluble orthophosphorus samples. The procedures outlined by Creitz and Richards[6] were followed. On other occasions, the membrane filters used in preparation of soluble orthophosphorus samples were used for determination of total suspended solids as outlined in Standard Methods for the Examination of Water and Waste Water.[7] Modifications included the use of 0.45 micron membrane filters and vacuum dessication over dried calcium chloride instead of drying at 103° centigrade.

Nitrates, fluorides and chlorides were measured with specific ion electrodes using an Orion Model 104 Specific Ion Meter. A two-point calibration method was used in all cases. Solid state fluoride and chloride electrodes and a liquid membrane nitrate electrode were used in accordance with the manufacturer's recommendations.

Conductivity was measured with a conductivity bridge according to Standard Methods. A glass electrode was used for pH measurements. For both of the above measurements and the specific ion measurements, the sample temperature was adjusted to 25° Centigrade in a water bath.

Alkalinity and B.O.D. were done according to Standard Methods. A B.O.D. probe was used in combination with Y.S.I. Model 54 oxygen meter for oxygen measurement. It was calibrated daily with the azide modification of the Winkler Test. Field measurements of D.O. also used a Y.S.I. Model 54 meter and probe. The air calibration method, as recommended by the manufacturer, was used for calibrating the probe for field measurements of oxygen.

Quality Control

The procedures which were used were all standard methods and the precautions accompanying the description of the methods were followed. Most of the measurements involved the use of standard solutions in the calibration of the equipment which was done on a daily basis. For all of the phosphate tests, three known concentrations were used with each series of tests.

Normally, replicate samples were obtained at two sampling locations on each collection trip. The replicates were treated as "unknowns" and were subjected to all of the analyses that were done on the identified samples. The data obtained for the replicates generally showed excellent agreement with the corresponding river samples.

SECTION VI

DATA STORAGE AND PRESENTATION

Data Storage

The water quality monitoring program outlined in the preceding section produced in excess of 200 bits of data per day of sampling. Computer programs were developed for storing and analyzing this data using an I. B. M. 1130 Computer System. After the analyses for a given sample were completed, the data for that sample were placed on two I. B. M. computer cards. The arrangement of data on the cards is shown in Table II. The information was then transferred to a computer disk where it was arranged by calendar date for each station.

For those collection stations where stage-flow tables were available (S-10, S-26, S-52, and T-20), the information relating stage to flow in C. F. S. was also stored on the disk. This information, together with the stage measurements, allowed the calculation of the momentary flow and momentary flux for any of the data at these stations. The U. S. G. S. provided interim data for the mean daily flows at the above stations and this information was also transferred to the disk for use in estimating total daily fluxes.

Graphical Presentation of Data

A computer program was designed to graphically show the relationship between any two variables at a given collection station. The following sections include graphs showing the relationship between the concentration of a variety of chemicals and flow volume, the flux of these same chemicals as a function of flow volume, the concentration of a variety of chemicals as a function of conductivity and the relationship of total phosphorus concentration to total suspended solids. In generating these graphs, the computer surveys all of the data at a given station during a specified time interval and picks out those samples for which both variables are listed. The computer then determines the maximum and minimum values for the Y- and X-axis variables. For the Y-axis the interval

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TABLE II. Computer Card Format for the Sandusky River Data

Card 1

Column	Information
1-4	Location
5-10	Date
11-15	Stage
16-19	Temperature (^{o}C)
20-23	DO
24-28	BOD
29-35	Fecal Coliform
36-39	Cl^-
40-42	F^-
43-46	pH
47-50	Conductivity
51-53	Nitrate
54-57	Alkaline
58-60	Orthophosphate
61-63	Total phosphate
64-66	Na^+
67-69	K^+
70-73	Ca^{++}
74-76	Mg^{++}
77-79	Blank
80	Card number = 1

Card 2

Column	Information
1-4	Location
5-10	Date
11-14	Seston
15-19	Total solids
20-23	Chlorophyll absorbance @ 665 mu
24-27	Chlorophyll absorbance @ 645 mu
28-31	Chlorophyll absorbance @ 630 mu
32-34	Chlorophyll volume filtered (liters)
35-37	Chlorophyll absorbance path length constant (K)
38-41	Fe
42-45	Cu
46-51	Cr
52-57	Zn
58	Blank
59-62	Time - 24 hour clock
63-79	Blank
80	Card number = 2

between the maximum and minimum values is divided into 50 equal parts, while for the X-axis, the interval is divided into 100 parts. A graph is then plotted on the printer using 50 vertical lines for values of Y and 100 horizontal spaces for values of X. The point pairs are thus plotted to the nearest one-fiftieth of the range between the maximum and minimum values for Y and the nearest one-hundredth of the range between the maximum and minimum values of X.

The above method of plotting the graphs has the advantage of giving a maximum spread of points. Its disadvantage lies in the fact that the values of Y and X listed along these axes are not integral values but instead are values spaced evenly between the maximum and minimum values for the variable. Care must be taken to actually look at the numbered values along the axes since they will differ considerably from graph to graph.

After each graph is plotted, the point pairs for that graph are listed. Where data are clustered it is possible that more than one point-pair will be represented by a single point on the graph.

It is possible to establish a specific range of values for the X-axis. For example, where a closer look at the relationship between concentration and flow at low flows is desired, the "scale" of the low flow values can be set so that these values extend across the entire X-axis.

The graphs which are presented in this report have been traced directly from the computer printouts. The values for the Y- and X-axis have been retyped using larger type. The resulting graphs were then photographically reduced to the form in which they are included.

Tabular Presentation of Data

Programs have been written for three different tabular or "appendix" arrangements of the data. The first arrangement summarizes all of the data for a given station. The individual variables are listed across the page. For each variable, space is provided for both concentration and flux. The linear sequence in these tables corresponds to the calendar date.

The second arrangement treats a single variable at a time and lists the concentration or flux of that variable at each of the collection sites. The appendix has room for ten collection sites across the page. Again the linear sequence of data corresponds to the calendar date. Data included in the appendices of this report are presented in this form.

The third appendix treats a single variable at a single station. It lists the date, the concentration, the momentary flow, the momentary flux, the mean daily flow, and the flux calculated from the mean flow. The fluxes are expressed as pounds per day.

SECTION VII

RIVER CONDITIONS

During the period of this study there was an absence of low flow conditions in the river. Table III shows the flows which are exceeded 80% and 90% of the time, and the average low flow during 2-year frequency, 7-day duration low flow periods. Information is included for all three gage stations on the Sandusky River. The table also includes the four lowest flows observed at each of these stations during sample collections. Examination of interim flow data provided by the U.S.G.S. confirms that, during the period of this study (January 1, 1969 through June 30, 1970), on no occasion did the flow fall to the 80% level at stations S-52 and S-26 and on only 2 days did the flow reach the 80% level at S-10.

The lowest flows observed during this study were 3- to 4-fold greater than the average low flow during 2-year frequency, 7-day duration low flow periods. In fact, the lowest flows observed exceed the anticipated augmented flow levels. Thus, in terms of flows, the data which we have available correspond more closely to the expected conditions during flow augmentation than during low flow periods.

During subsequent sections of this report the term "low flow" will be used for the lowest flows observed during this study. The term "severe low flow" will be used with reference to flows less than those equalled or exceeded 80% of the time, such as the average low flow during 2-year frequency, 7-day duration low flow periods. The term "severe low flow" should not be construed as the "drought of record" but can consist of substantially higher flows than during such droughts.

TABLE III. Comparison of Low Flow Frequency Data and Low Flows Observed During This Study

Station	Discharge Exceeded 80% of Time * C.F.S.	Discharge Exceeded 90% of Time ** C.F.S.	2-Year Frequency 7-Day Duration Average Low Flow ** C.F.S.	Lowest Flows Observed During This Study C.F.S.	Date
S-52	12.9	6.40	4.20	15	9/16/69
				16	9/01/69
				18	8/15/69
				18	10/14/69
S-26	34.5	20.5	13.5	51	9/01/69
				55	9/16/69
				60	8/29/69
				64	8/14/69
S-10	52.1	31.0	22.0	64	8/15/69
				68	8/29/69
				68	10/29/69
				75	8/28/69

* Data from Northwest Ohio Water Development Plan

** Data from Low-Flow Frequency and Storage Requirement Indices for Ohio Streams

SECTION VIII

RELATIONSHIP BETWEEN CONCENTRATION OF CHEMICALS AND RIVER FLOW

A basic assumption justifying the construction of flow augmentation facilities is that water quality is lowest when natural stream flow is lowest. Certainly where there is a relatively constant influx of degrading materials into a stream, such as from a sewage treatment plant or an industry, as natural stream flow decreases there is less water to dilute the wastes and the wastes are therefore more concentrated. If the degrading materials come into the stream as part of surface runoff water from either rural or urban areas, then the relationship between river flow and concentration of wastes is more difficult to predict. Likewise, it is difficult to predict the relationship between river flow and the concentration of "background" chemicals which comprise the natural chemical makeup of the water and upon which are superimposed the "effluents" of man's agricultural, domestic and industrial activities. It should also be noted that several of the substances which are included above under the term "wastes" are also natural components of the streams. Plant nutrients are an important example of this.

Since one of the major objectives of this study was to determine the effects of flow augmentation on a wide variety of water quality parameters, the first step consisted of investigating the relationship between the concentration of several chemicals and the flow volume in the stream.

The results of these investigations are shown in Figures 4-13. Each figure consists of 4 graphs. Each graph shows the relationship between the concentration of a single chemical and volume of stream flow at one of the four U.S.G.S. stream gages (sampling locations S-52, T-20, S-26, and S-10). The method by which these graphs were plotted has been outlined in Section VI of this report. In all cases, only the data collected between July 1, 1969 and October 30, 1969 are included in the graphs since this 4-month period encompasses the time when low flows are most common and consequently received the most intensive surveillance.

In comparing the 4 graphs in each figure, note that station S-52 is located less than one mile downstream from the outfall of the Upper Sandusky sewage treatment plant. The drainage basin upstream from station T-20 is entirely rural. Stations S-26 and S-10 are on the mainstream but are located upstream from Tiffin and Fremont, respectively. Station S-26 is approximately 30 miles downstream from the Upper Sandusky sewage treatment plant and station S-10 is 18.5 miles downstream from the Tiffin sewage treatment plant.

For purposes of discussion the chemicals studied have been somewhat arbitrarily divided into three groups--"background" chemicals, plant nutrients, and B.O.D. and D.O. Fluoride, sodium, magnesium and calcium are included under the term "background" chemicals. As a group, these chemicals show increasing concentrations as the volume of stream flow decreases. Specific conductivity is included under this heading. Total phosphorus, soluble orthophosphorus, nitrate-nitrogen and potassium are discussed under the heading of plant nutrients. For these, the relationship between concentration and stream flow shows the effects of multiple input sources. Since the concentration of both B.O.D. and D.O. clearly reflect the effects of stream metabolism as well as input sources, they are discussed separately as a third group.

Background Chemicals

Figure 4 shows the relationship between specific conductivity and flow. It is apparent that there were considerable variations in conductivity and flow during this period. The high conductivity values tend to occur during periods of low flow and low conductivities predominate during periods of high flow. There was, however, considerable variation in the conductivities observed during the periods of low flow. For example, at the lowest flows plotted for Station S-52, the conductivity ranged from about 550 micromhos to 970 micromhos.

The pattern of high conductivity at low flow and low conductivity at high flow is most evident in the upstream stations at S-52 and T-20. Stations S-26 and S-10 have somewhat lower conductivities than the upstream stations and have more variation in conductivity in the higher flow ranges. Nevertheless, the pattern of high conductivity at low flow and low conductivity at high flow is still apparent at these downstream stations. The larger drainage basins above the downstream stations could account for more variability within a narrower range of values at these locations. The upstream stations with smaller drainage basins are more likely to encounter uniform weather and rainfall conditions within their basins.

Several chemicals show a pattern of relationship between concentration and flow that is quite similar to that for conductivity. These include fluoride (Figure 5), sodium (Figure 6), magnesium (Figure 7), and calcium (Figure 8). All of these show increasing concentrations as the volume of stream flow decreases. As pointed out earlier, a pattern of high concentration at low flow and low concentration at high flow would occur when there is a relatively constant rate of influx of materials into a receiving stream. Such constant rates of influx could come from a sewage treatment plant or industry. The above pattern would be most pronounced when the constant influx represents a substantial portion of the total loading into the stream.

In the case of sodium, magnesium, calcium and conductivity, the pattern of high concentrations at low flows cannot be accounted for by decreasing dilution of a constant input. Instead the pattern reflects the relationship between the concentration of these chemicals in the surface runoff water and ground water and the volume of the surface runoff water and ground water. During periods of high runoff, and consequently high flow conditions in the river, the concentrations of these chemicals tend to be low. The large variations in concentration during periods of low stream flow could be accounted for by differing relative contributions of more concentrated ground water and more dilute surface runoff water which together make up the stream flow.

Three aspects of our data support this interpretation. First, given the assumption that the daily output of chemicals from

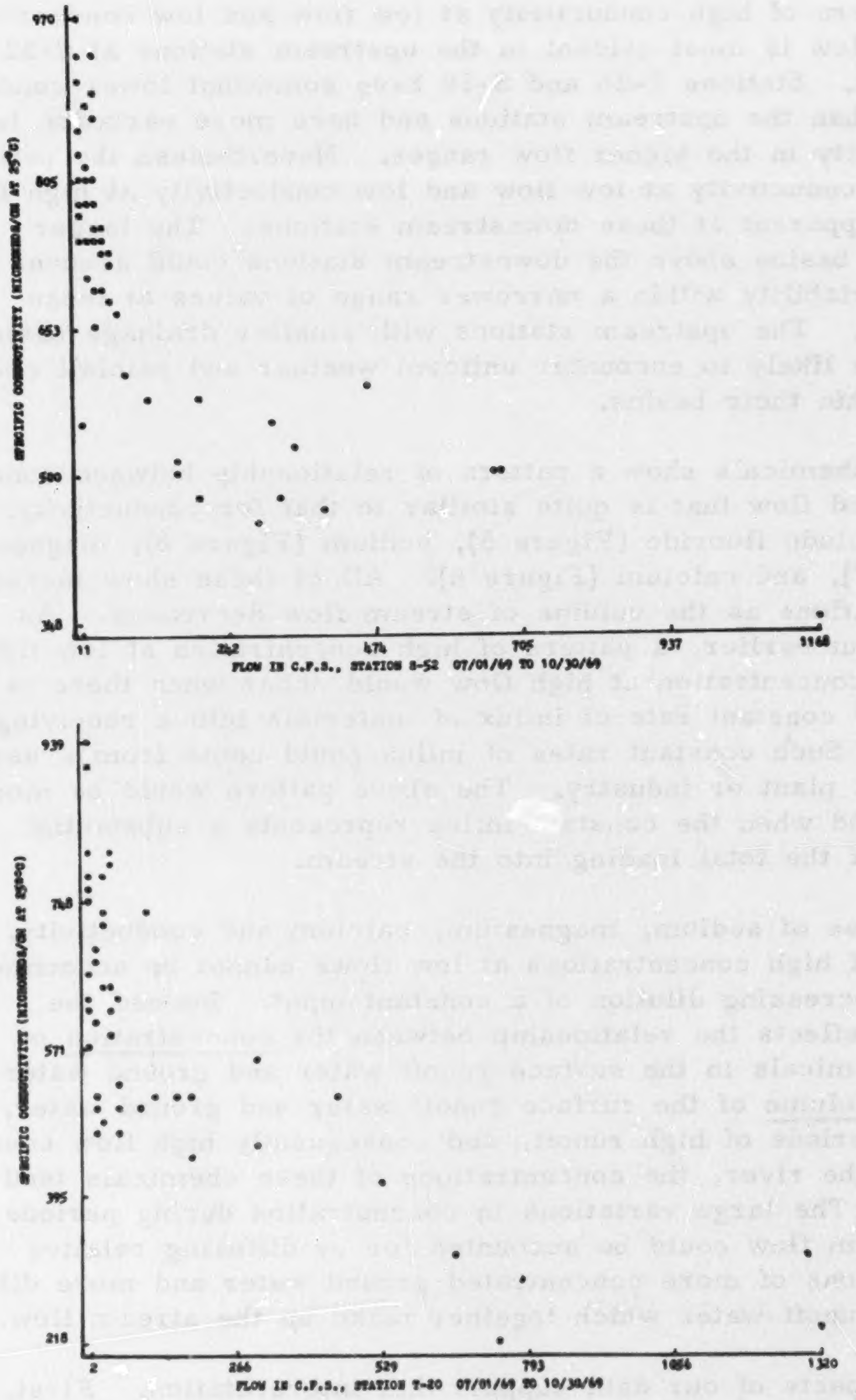


Figure 4. Relationship Between Specific Conductivity and Flow Volume

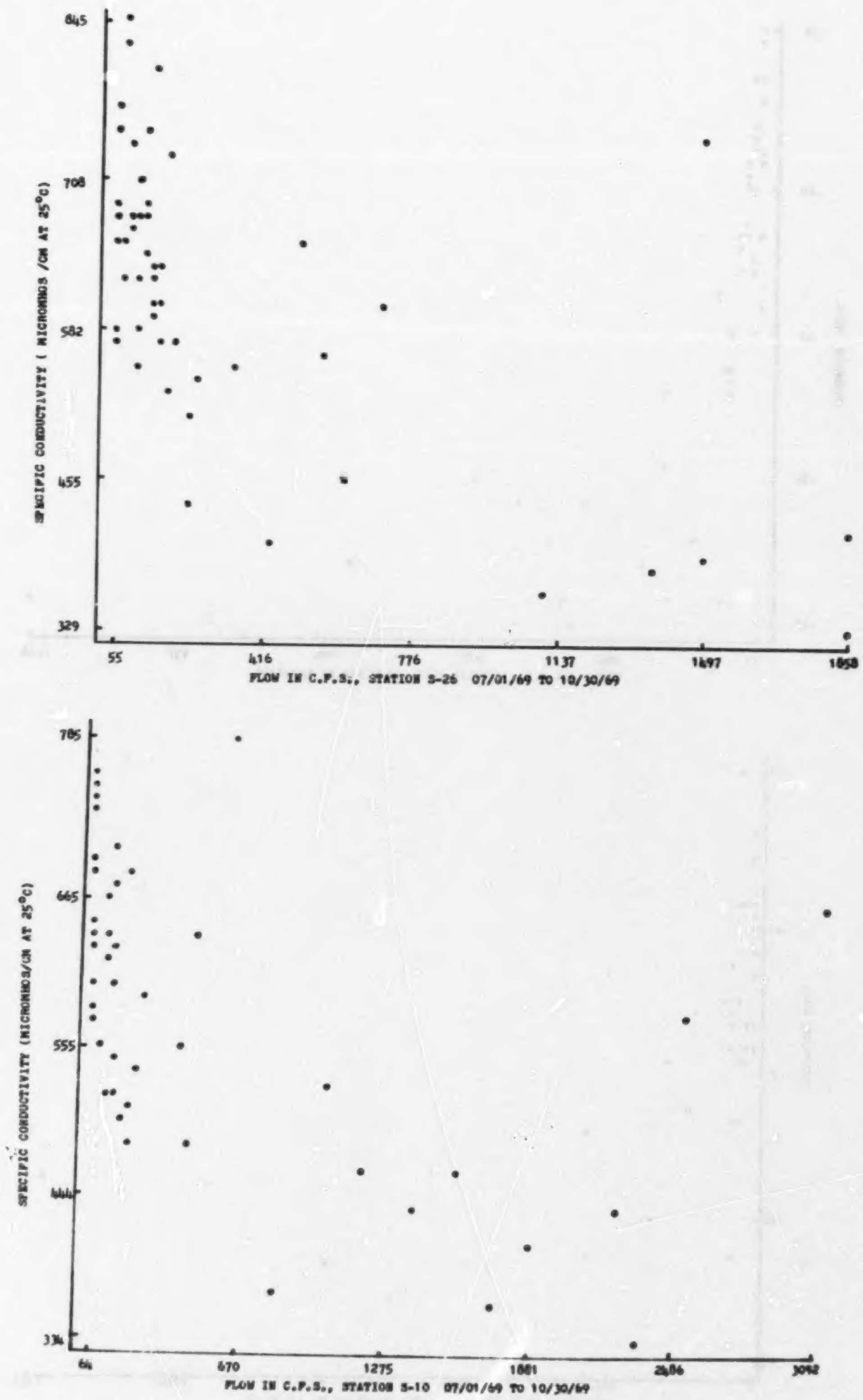


Figure 4 Continued

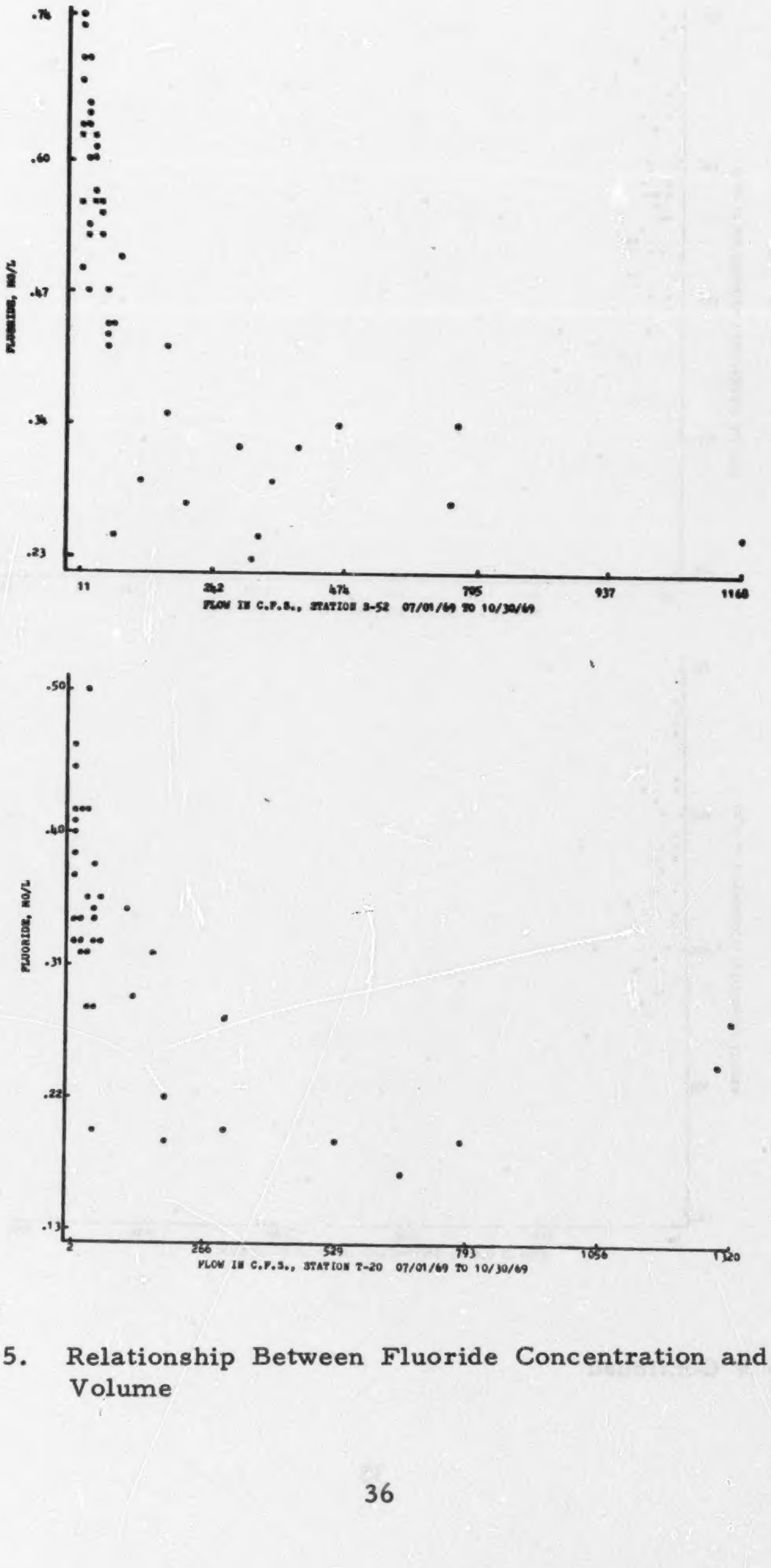


Figure 5. Relationship Between Fluoride Concentration and Flow Volume

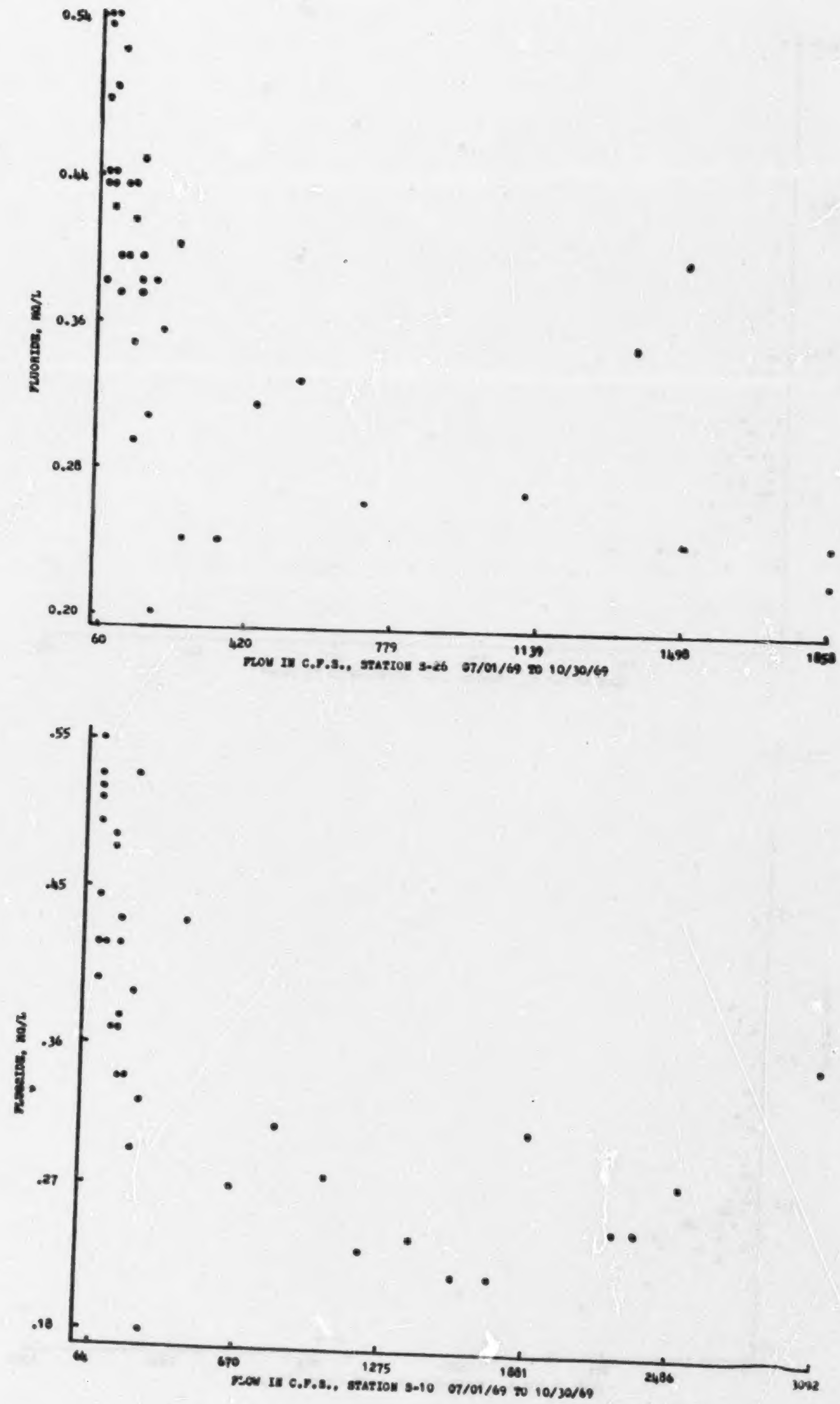


Figure 5 Continued

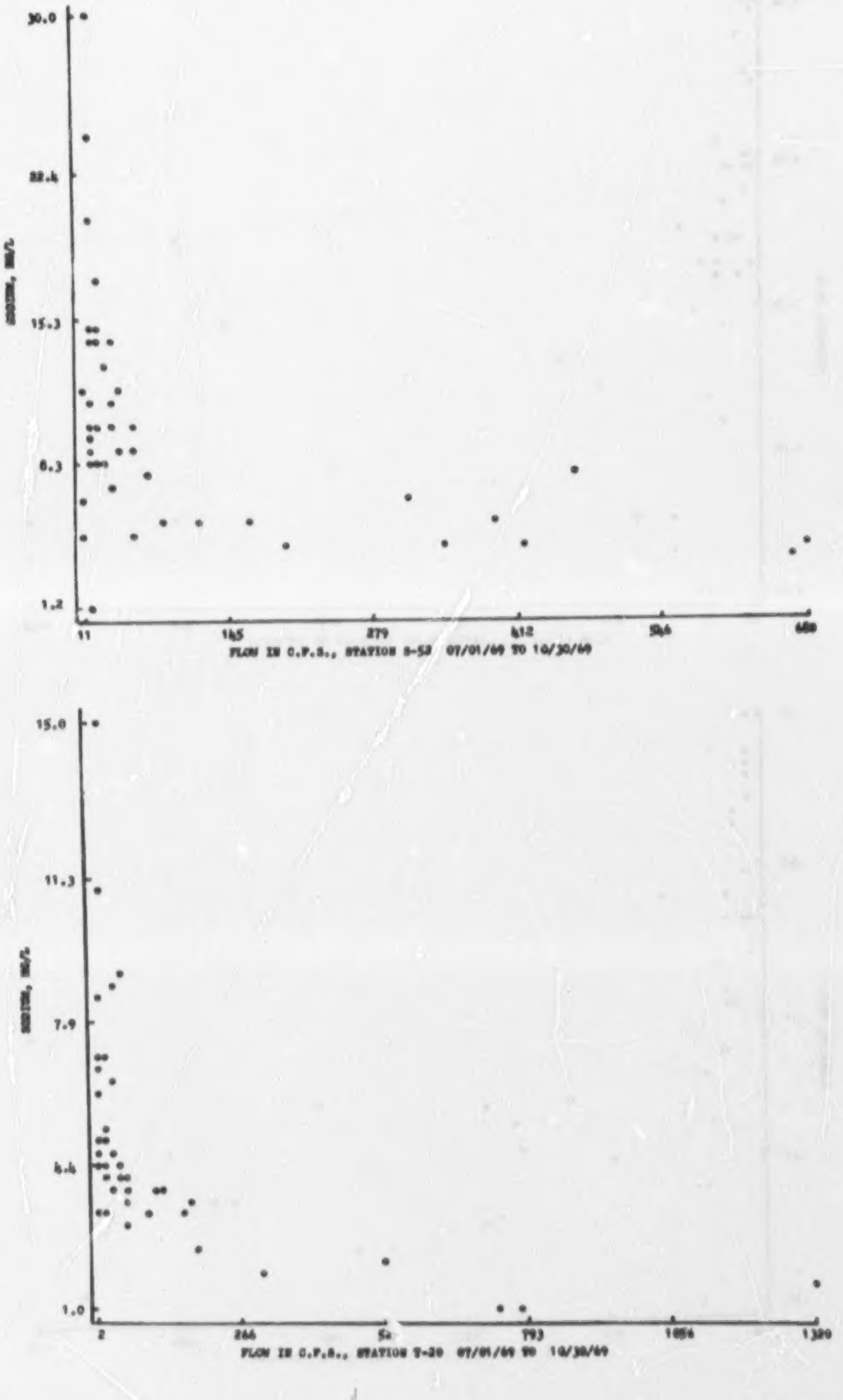


Figure 6. Relationship Between Sodium Concentration and Flow Volume

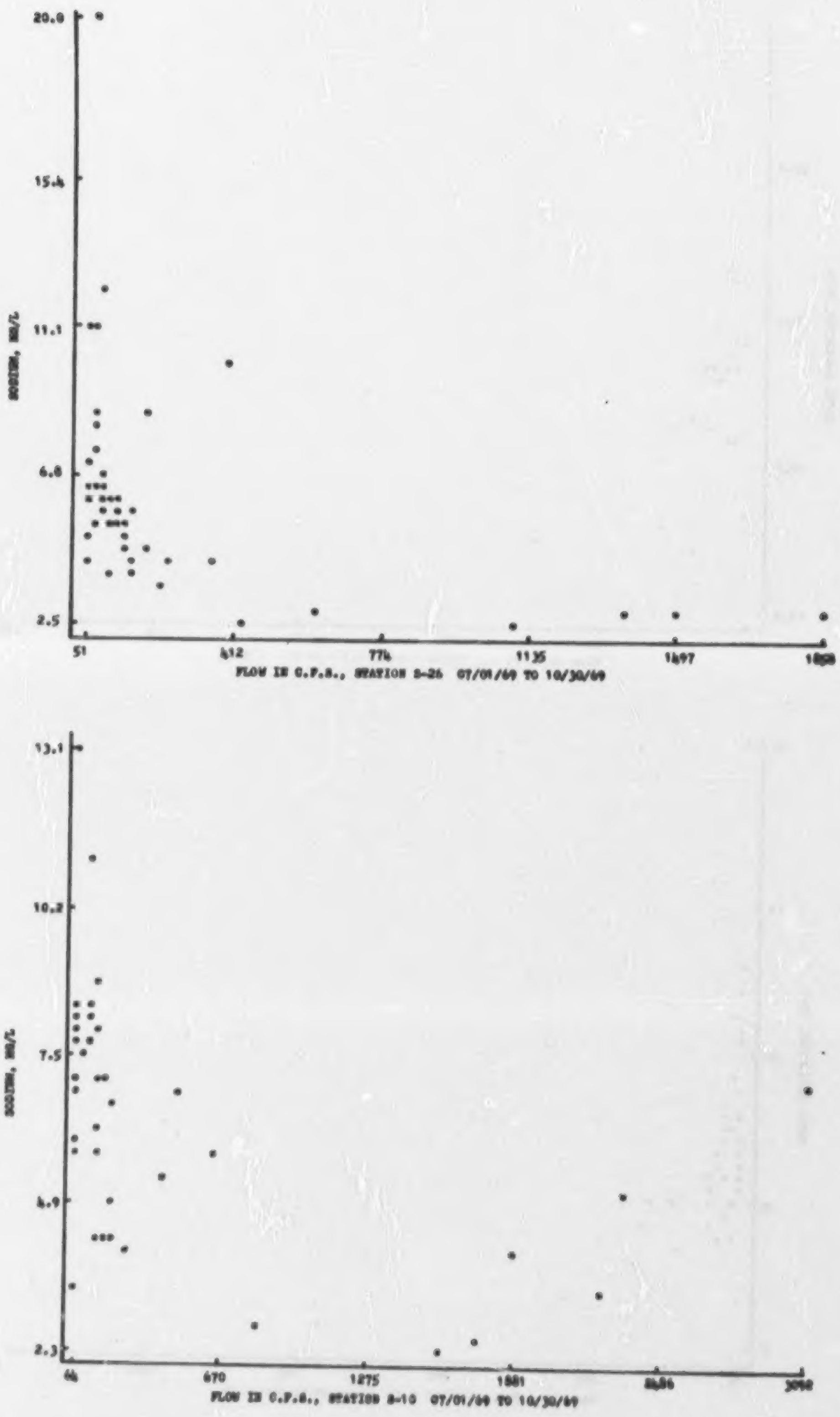


Figure 6. Continued

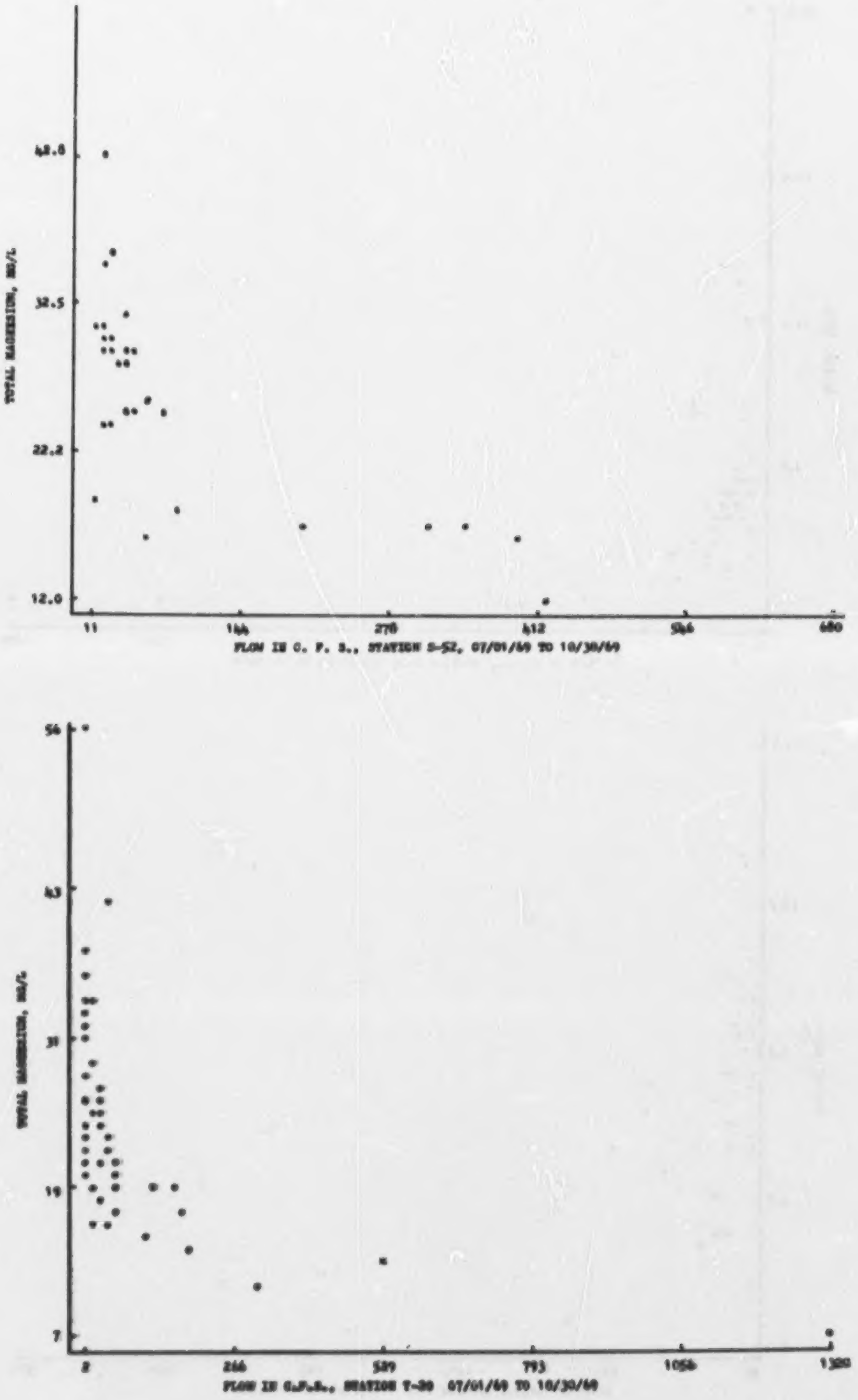


Figure 7. Relationship Between Magnesium Concentration and Flow Volume

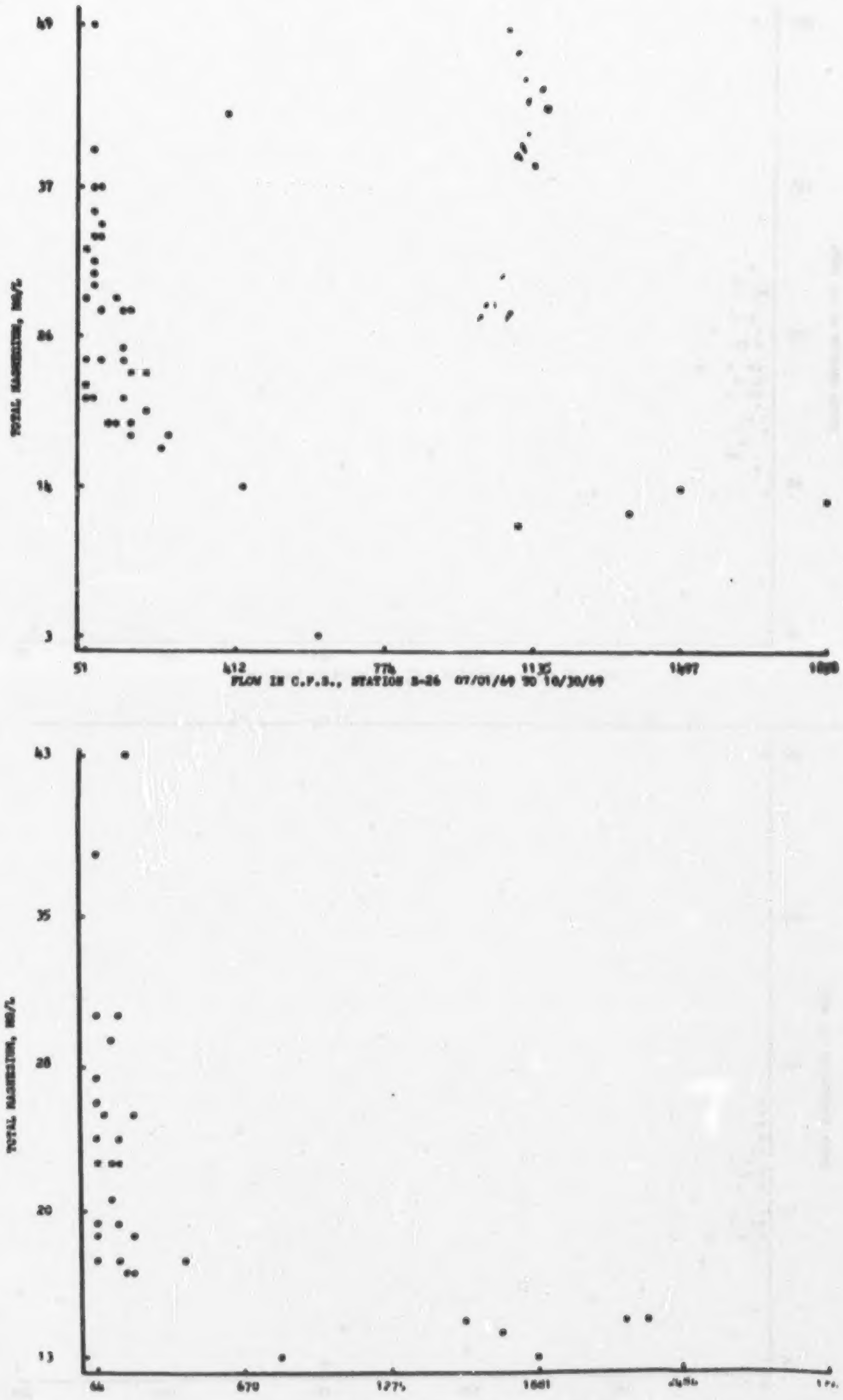


Figure 7 Continued

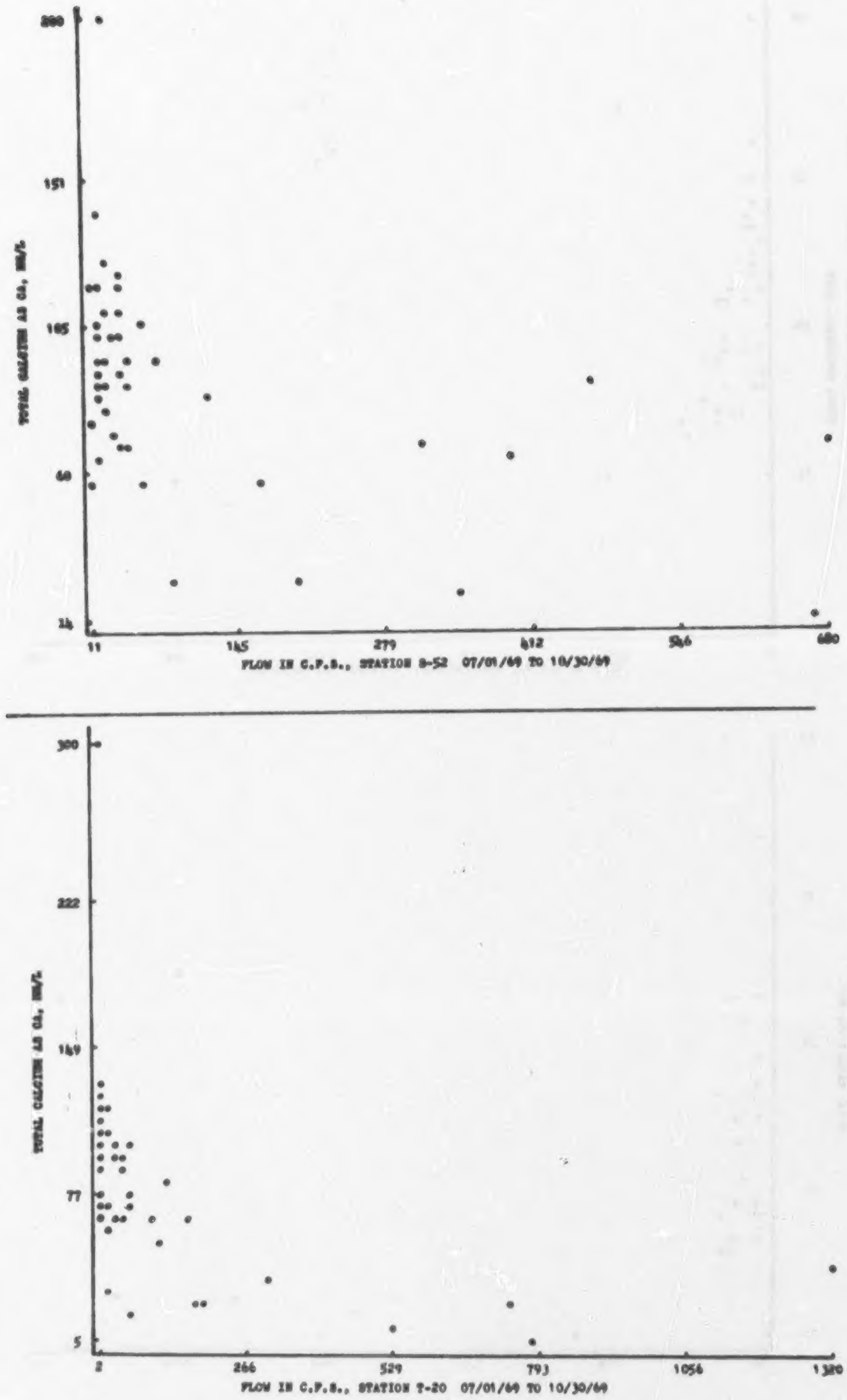


Figure 8. Relationship Between Calcium Concentration and Flow Volume

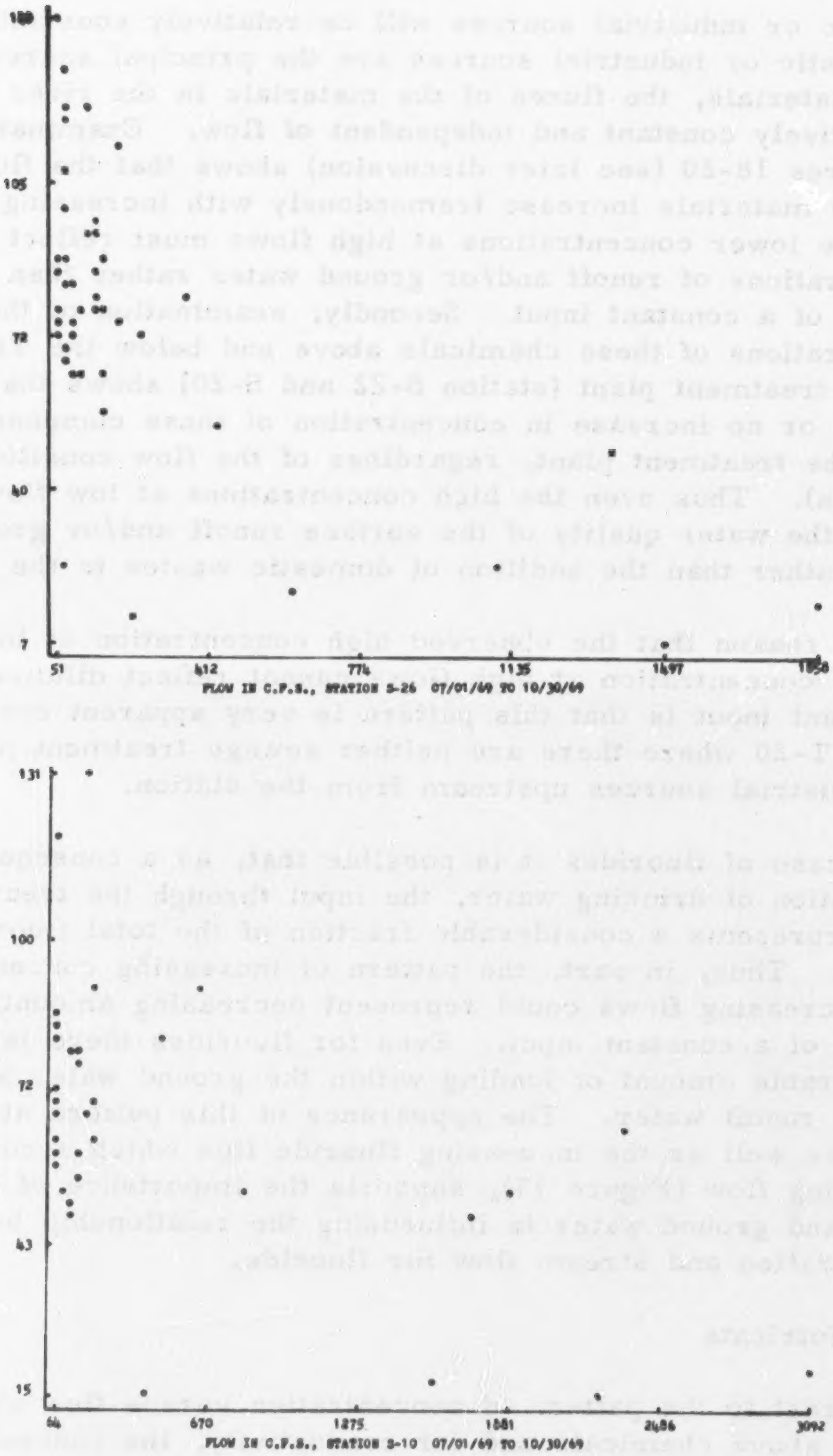


Figure 8 Continued

domestic or industrial sources will be relatively constant, then if domestic or industrial sources are the principal sources for these materials, the fluxes of the materials in the river would be relatively constant and independent of flow. Examination of Figures 18-20 (see later discussion) shows that the fluxes of these materials increase tremendously with increasing flows. Thus the lower concentrations at high flows must reflect the concentrations of runoff and/or ground water rather than a dilution of a constant input. Secondly, examination of the concentrations of these chemicals above and below the Tiffin Sewage treatment plant (station S-22 and S-20) shows that there is little or no increase in concentration of these components below the treatment plant, regardless of the flow condition (see Appendix). Thus even the high concentrations at low flows reflect the water quality of the surface runoff and/or ground water rather than the addition of domestic wastes to the river.

A third reason that the observed high concentration at low flows and low concentration at high flows cannot reflect dilution of a constant input is that this pattern is very apparent even at station T-20 where there are neither sewage treatment plants nor industrial sources upstream from the station.

In the case of fluorides it is possible that, as a consequence of fluoridation of drinking water, the input through the treatment plant represents a considerable fraction of the total fluoride loading. Thus, in part, the pattern of increasing concentrations with decreasing flows could represent decreasing amounts of dilution of a constant input. Even for fluorides there is a considerable amount of loading within the ground water and surface runoff water. The appearance of this pattern at station T-20, as well as the increasing fluoride flux which accompanies increasing flow (Figure 17), supports the importance of surface runoff and ground water in influencing the relationship between concentration and stream flow for fluoride.

Plant Nutrients

In contrast to the pattern of concentration versus flow observed for the above chemicals and for conductivity, the concentrations of

The major plant nutrients which are contained within fertilizers show either no consistent pattern with respect to flow or else, this is the case for total phosphorus, tend to show higher concentrations at higher flows. Figure 9 shows the relationship between the concentration of total phosphorus and flow. At station S-52 the concentration of total phosphorus at the low flow range does resemble the earlier pattern. At medium and high shows, however, the concentration remains at high levels. At stations T-20, S-26 and S-10 even at low flows the pattern is quite different from the earlier pattern. For these stations the total phosphorus concentration tends to increase with flow throughout the entire range of flows. There is considerable variation in total phosphorus concentration at any given flow.

In the case of total phosphorus, the relationship between concentration and flow reflects the contribution of two major sources into the river, domestic sewage and agricultural runoff. At station S-52 within the low flow range, the concentration increases with decreasing flow. This probably reflects decreasing amounts of dilution of the effluent from the treatment plant as flow decreases. The contribution of domestic sewage to the total phosphorus content of the river is also apparent from the increments of total phosphorus concentration above and below the Tiffin sewage treatment plant.

Table IV shows the effects of effluents from the Tiffin sewage treatment plant on the concentrations of a variety of chemicals. The data include the 10 highest flows and the 10 lowest flows during the July 1 through October 30 period. Station S-22 is about 0.5 miles upstream from the treatment plant while station T-20 is about 2.2 miles downstream. Phosphorus loading is especially apparent during low flow periods. In contrast to phosphorus, note that there is no significant increase in magnesium concentration above and below the treatment plant under either high or low flow conditions.

The effects of domestic loading of total phosphorus are not apparent at stations T-20, S-26 and S-52. At these stations the total phosphorus concentration actually decreases as flow volume decreases.

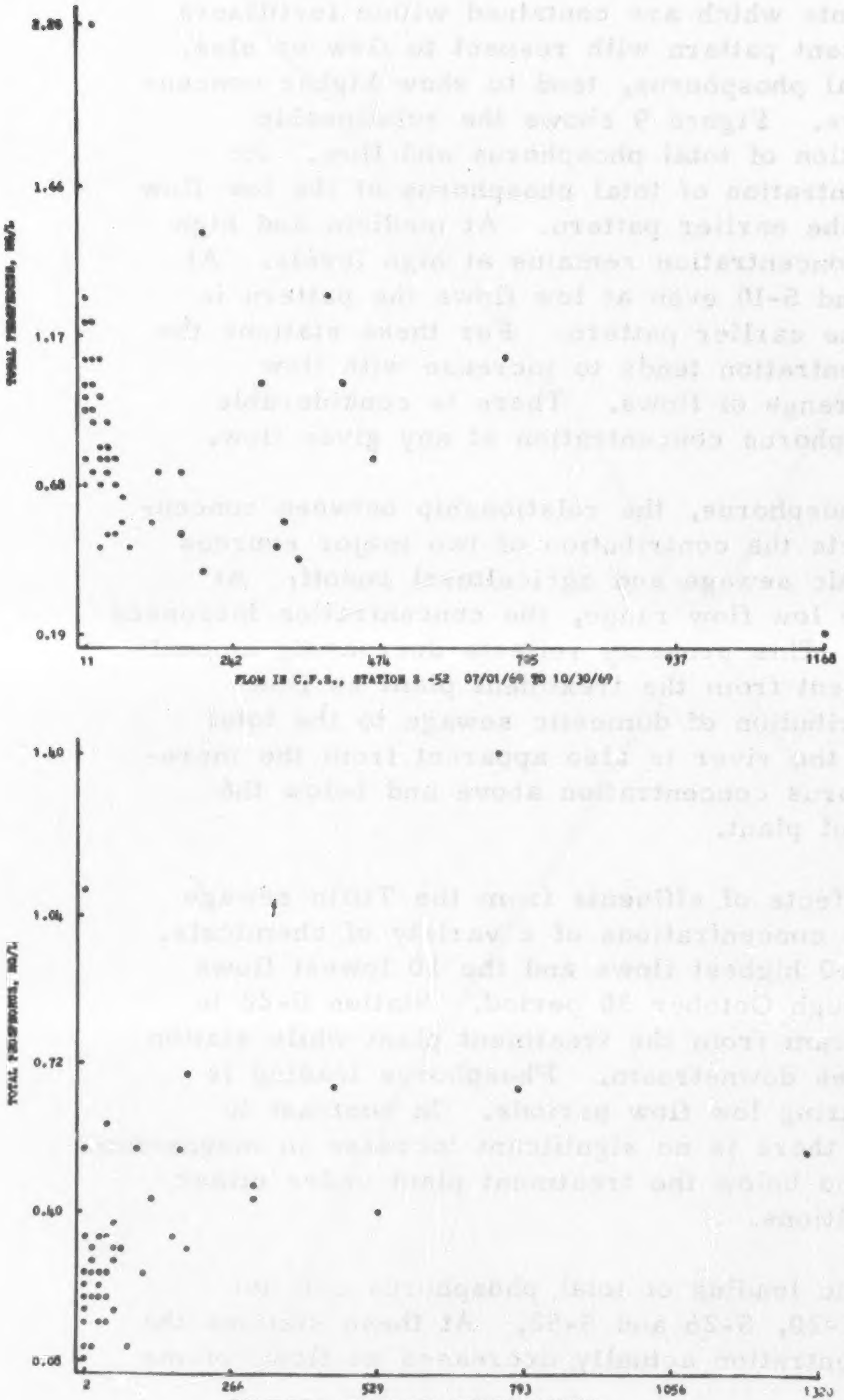
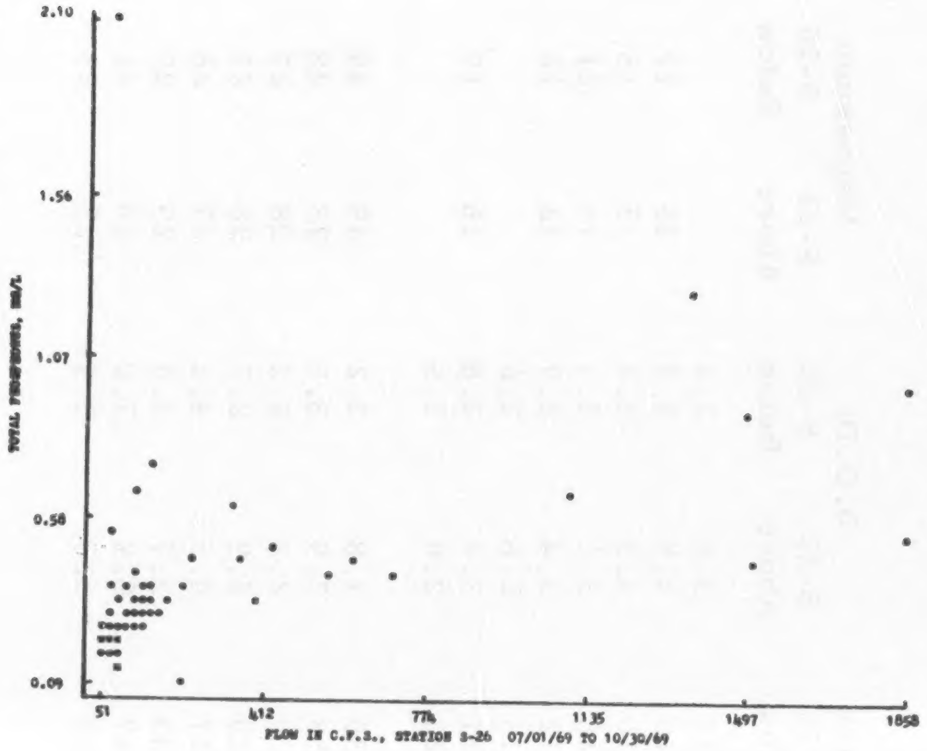


Figure 9. **Relationship Between Total Phosphorus Concentration and Flow Volume**



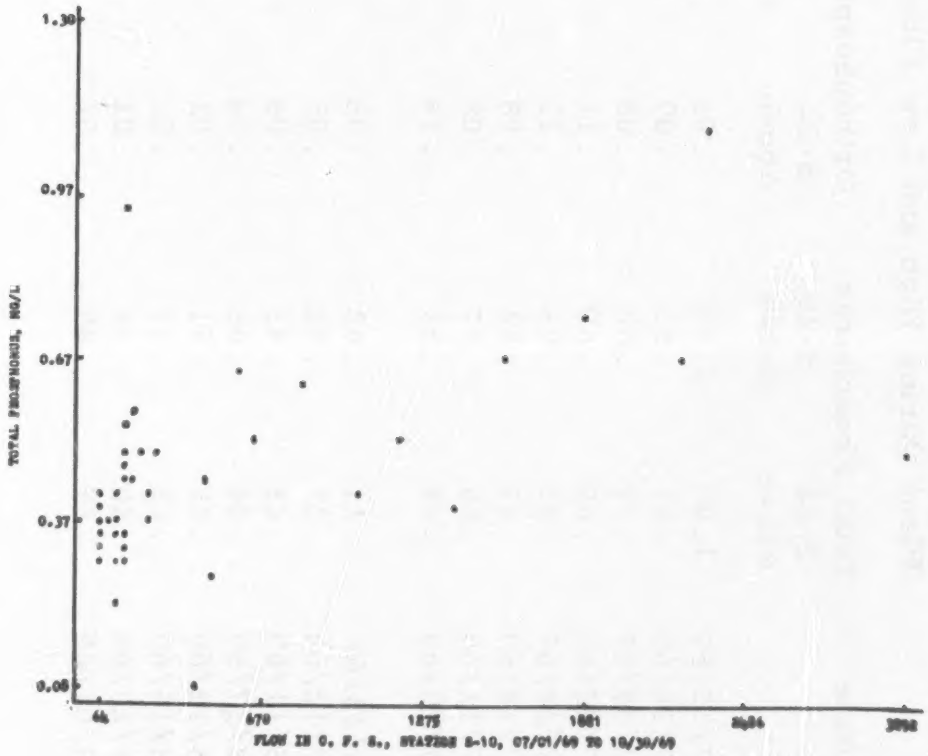


Figure 9 Continued

TABLE IV. Comparison of Total Phosphorus, Orthophosphorus, B.O.D. and Magnesium Concentrations Above and Below the Tiffin Sewage Treatment Plant During High and Low Flows

	Date	Total Phosphorus S-22 Above	Total Phosphorus S-20 Below	Orthophosphorus S-22 Above	Orthophosphorus S-20 Below	B.O.D. S-22 Above	B.O.D. S-20 Below	Magnesium S-22 Above	Magnesium S-20 Below
Highest Flows	7/23/69	1.00	1.10	.03	.35	3.4	2.4		
	7/10/69	.51	.55	.09	.13	5.8	5.2	16	17
	7/09/69	.79	.82	.08	.10	4.3	4.1	15	15
	7/22/69	.60	.60	.11	.18	3.1	3.1	19	21
	7/24/69	.82	.93	.12	.12	3.4	2.7	12	12
	7/14/69	.47	.52	.08	.15	2.6	2.6		
	7/11/69	.56	.57	.08	.11	3.4	2.8	16	17
	7/15/69	.44	.52	.14	.23	2.0	2.5		
Lowest Flows	10/23/69	.11	.42	.03	.35	1.8	2.2	49	49
	8/12/69	.23	.72	.05	.58	2.9	3.3	28	28
	8/11/69	.24	.43	.04	.29	2.9	2.2	28	27
	8/27/69	.44	.68	.04	.29	2.9	2.2	28	27
	8/18/69	.25	.51	.02	.27	4.3	4.2	27	26
	8/15/69	.18	.47	.02	.33	3.7	3.4	29	29
	8/29/69	.26	.75	.01	.47	8.8	7.0	20	21
	9/01/69	.27	85	.02	.65	5.9	3.9	23	23

At all of the gage stations the high concentrations of total phosphorus during periods of medium and high flow reflect the high concentrations of phosphorus in the surface runoff water. During periods of high surface runoff considerable sheet erosion takes place and large quantities of silt are carried into the stream. The binding of phosphates to the silt particles probably accounts for the high phosphate concentrations present in the runoff water. Such binding of phosphates to silt is well established.[8]

The relationship between soluble orthophosphorus concentration and flow is similar to that for total phosphorus (Figure 10). They differ in that most of the phosphorus entering the stream from sewage treatment plants is soluble orthophosphorus whereas most of the phosphorus accompanying silt runoff shows up only in the total phosphorus test. Also the concentration of soluble orthophosphorus is much more subject to modification through biological processes than is the concentration of total phosphorus. For example, phosphorus taken up by phytoplankton disappears as soluble orthophosphorus but remains a part of the total phosphorus measurement.

For orthophosphorus (Figure 10) at station S-52 the earlier pattern with high concentrations at low flows and low concentrations at high flows is very apparent. At T-20 the pattern is similar to the total phosphorus pattern. At the remaining two stations, S-26 and S-10, there is no apparent pattern with both high and low concentrations occurring within the entire range of flow conditions.

Figure 11 shows the relationship between nitrate-nitrogen concentration and flow. The scatter within the nitrate-nitrogen graphs is probably a consequence of two factors. One, domestic sewage is not a significant contributor to the nitrate-nitrogen content of water and, consequently, dilution effects downstream from treatment plants will not be present. This is indicated by the fact that the concentration of nitrate-nitrogen is in the same range at S-52 as at the other stations and by the fact that there is little significant increase in concentration above and below the Tiffin sewage treatment plant (see Appendix).

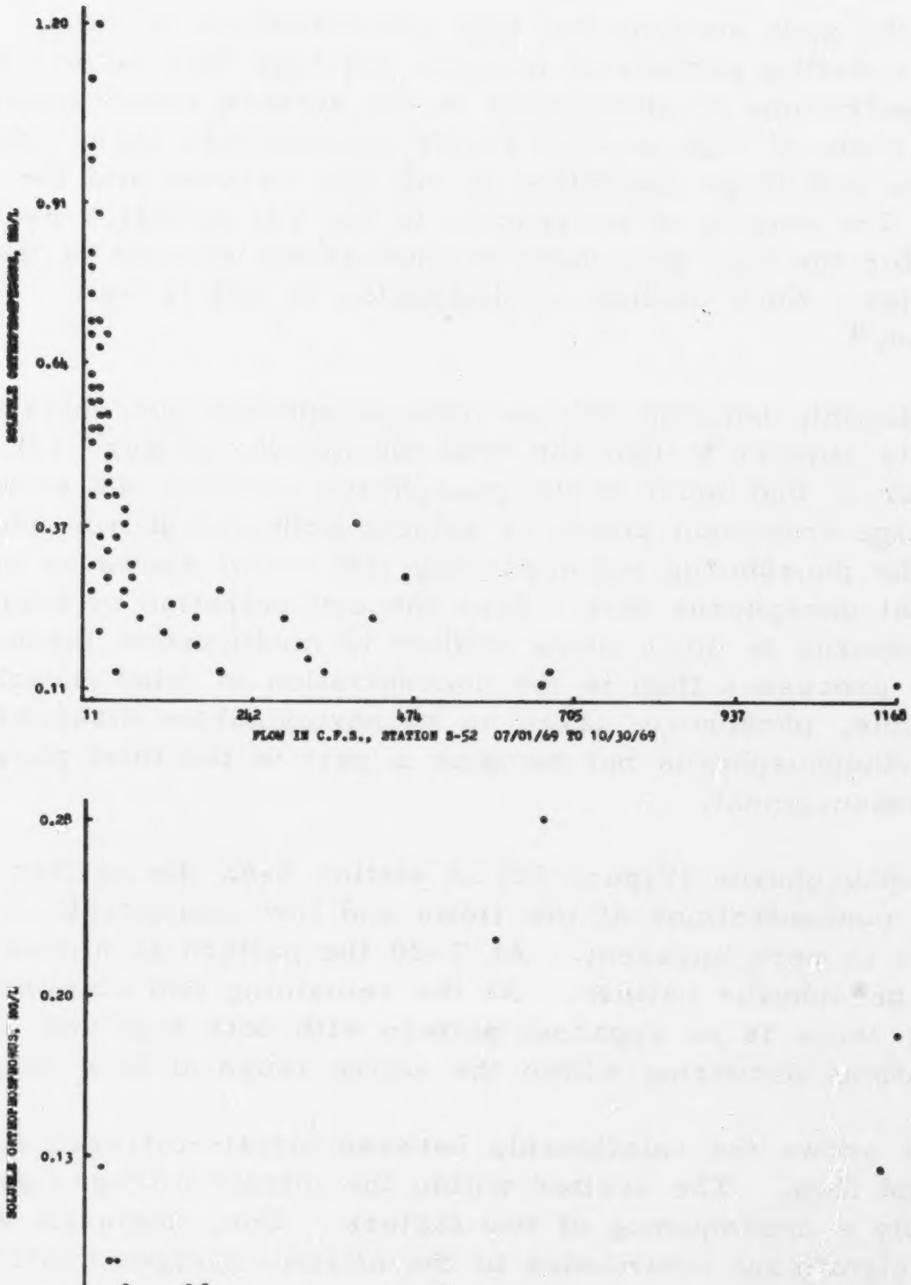


Figure 10. Relationship Between Soluble Orthophosphorus Concentration and Flow Volume

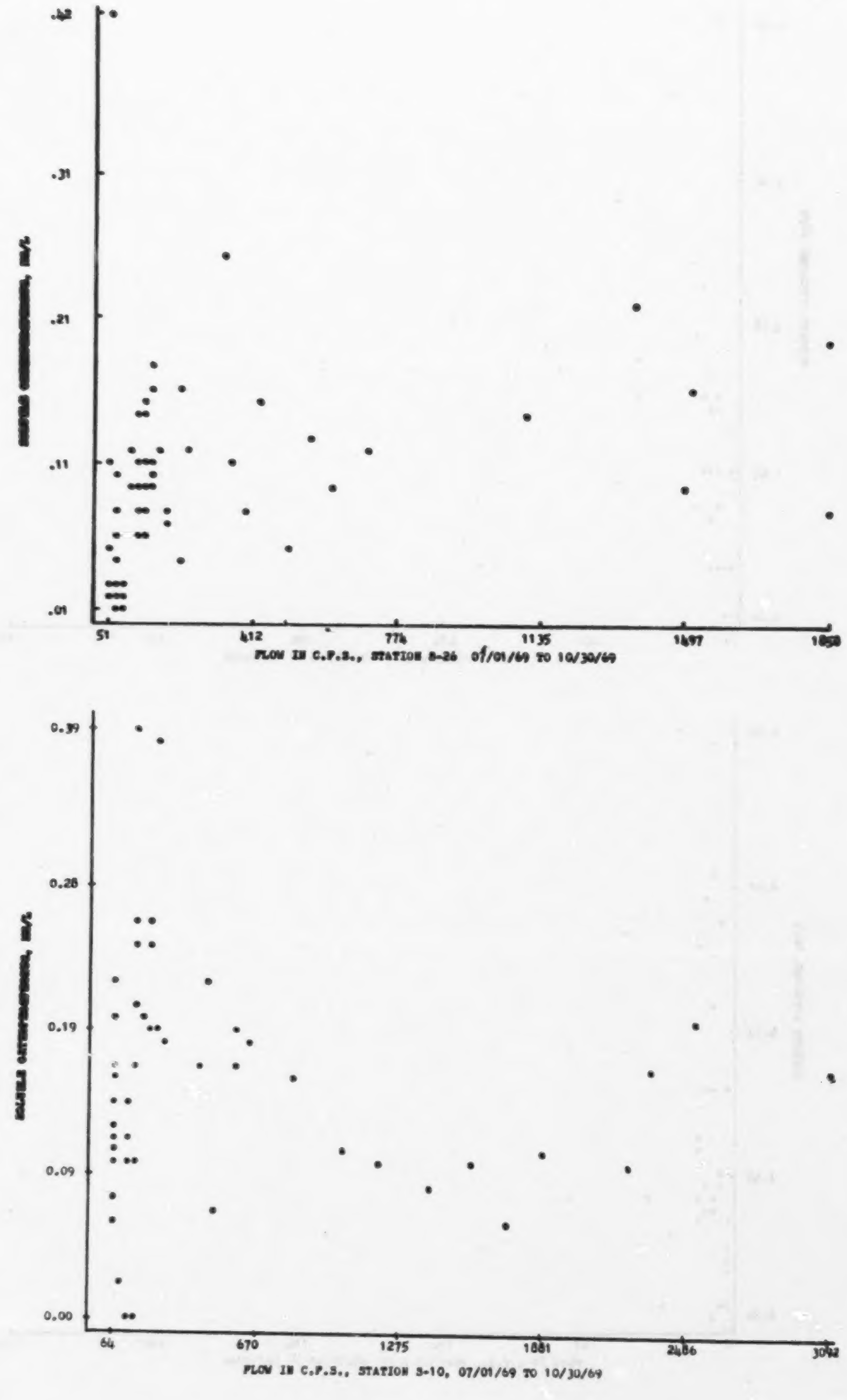


Figure 10 Continued

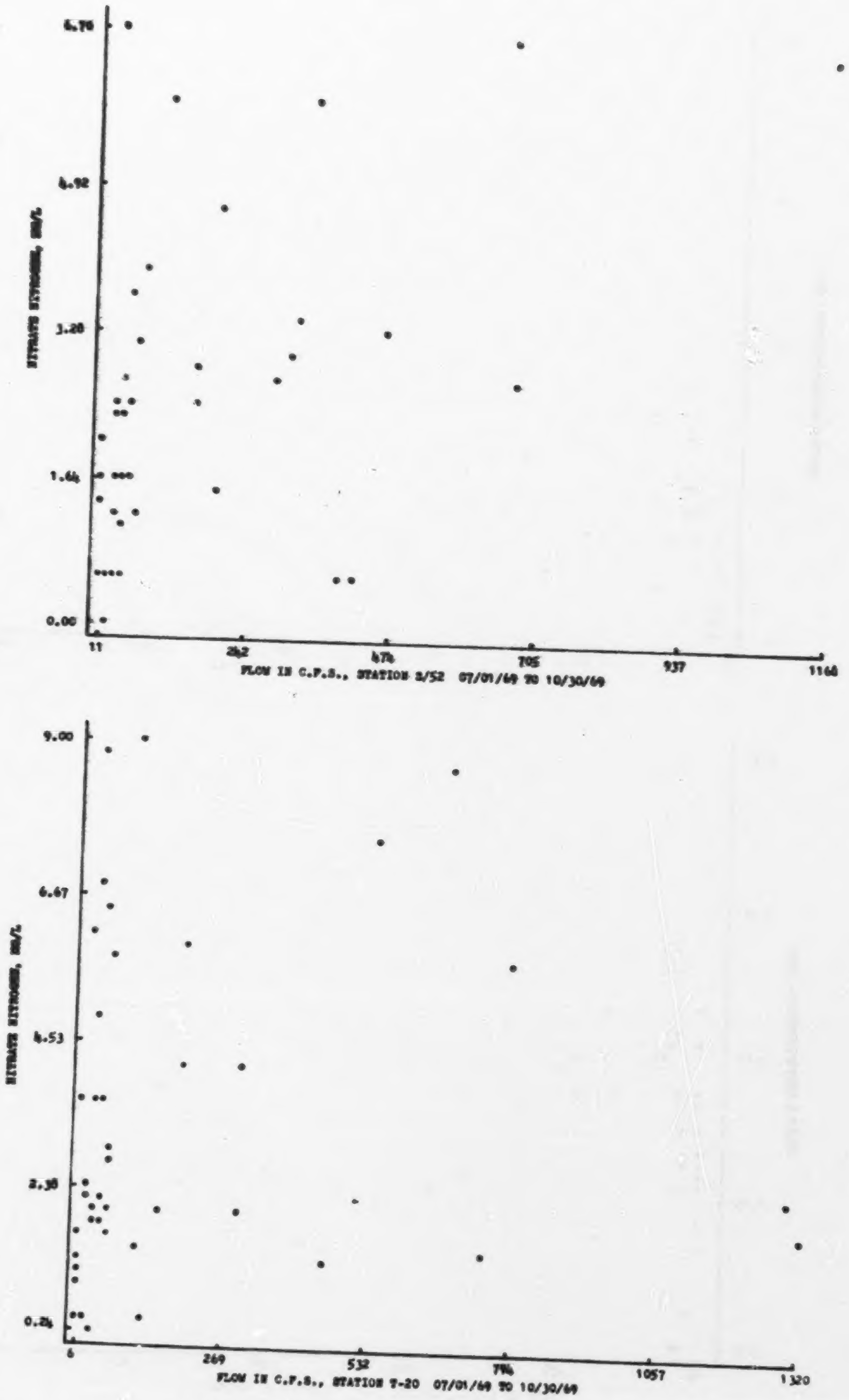


Figure 11. Relationship Between Nitrate Nitrogen Concentration and Flow Volume

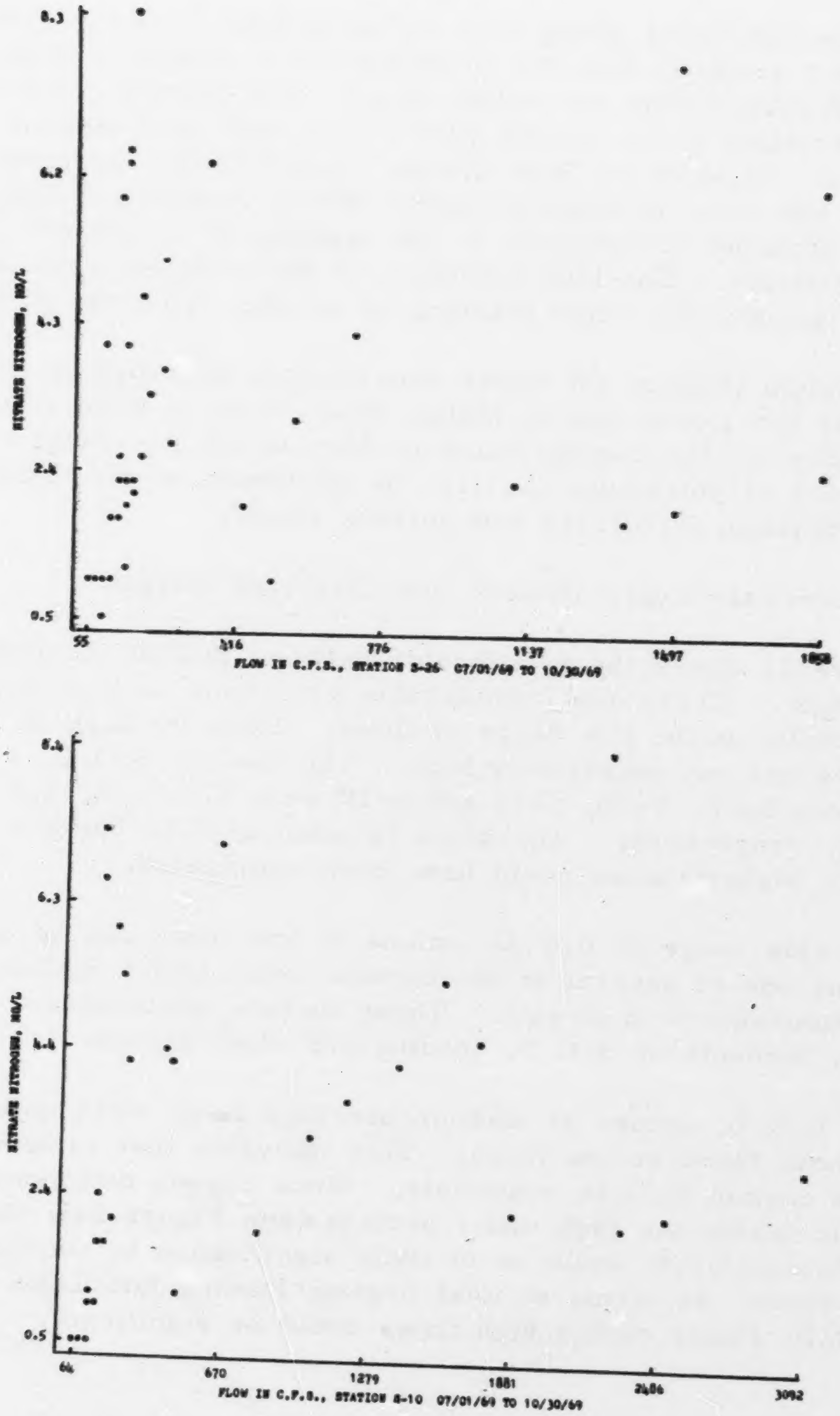


Figure 11 Continued

The second factor giving rise to the scatter in the nitrate-nitrogen graph is that the concentration of nitrate-nitrogen varies considerably within the runoff water. The nitrate concentration is correlated more closely with season than with amount of runoff per se. Most of the high nitrate concentrations occurred in July while low concentrations occurred during August and September. This probably corresponds to the application of nitrogen fertilizer to the fields. The high solubility of the nitrogen fertilizers could account for rapid leaching of nitrates from the soils.

Potassium (Figure 12) shows considerable variation in concentration at low flows, and at higher flows there is little if any tendency for the concentration to drop to the low range. This behavior of potassium can also be attributed to the application of potassium fertilizers and surface runoff.

Biochemical Oxygen Demand and Dissolved Oxygen

Figure 13 shows the relationship between B.O.D. concentration and flow. There are considerable variations in B.O.D., especially at the low range of flows. Even the high B.O.D. values are not excessively high. The median B.O.D. values at stations S-52, T-20, S-26 and S-10 were 5.0, 2.6, 3.3 and 3.9 mg/l, respectively. Given the location of S-52 below a treatment plant, higher values could have been anticipated.

The wide range of B.O.D. values at low flows can be attributed to any one of several of the factors which affect B.O.D.-D.O. relationships in a stream. These include temperature, rate of flow, amounts of B.O.D. loading and algal growth.

The B.O.D. values at medium and high flows were quite similar to those found at low flows. This indicates that surface runoff does contain B.O.D. materials. Since oxygen deficiencies do not occur during the high water periods (see Figure 14), the presence of this material would be of little significance to conditions in the river. In terms of total organic loading into Lake Erie, the B.O.D. fluxes during high flows could be significant.

The concentrations of oxygen as a function of flow is shown in Figure 14. The oxygen concentrations which are plotted are those which were observed at the time of sample collection and consequently represent neither the highest nor the lowest D.O. at a given station on a given day. Sample collections were done during the morning hours and the collection route was reversed on alternate days so at a given station the D.O. measurement does not represent the same time of day.

The graphs are nevertheless quite instructive in showing that at low flows the concentrations range widely both above and below saturation values while at medium and high flows the concentrations are near saturation levels. The wide variations in D.O. during low flow conditions are most likely due to the presence of algae. The algae could be responsible for both the high and low D.O. values, depending on time of collection and weather conditions. Effects of B.O.D. could also be involved in the low D.O. values observed during the low flow periods. This would certainly be the case at station S-52. The D.O. values at other sampling locations fell in the same range as those shown for the gage stations in Figure 14 (see Appendix).

Four water quality monitors which provide continuous records of D.O. are located along the Sandusky River and Tymochtee Creek. A summary of D.O. data from these monitors is shown in Table V. Unfortunately the monitor at S-52 was out of order for most of the low flow period. The monitor near Mexico is about two miles upstream from the stream gage at S-26 where our measurements are made. The monitor at Fremont is located downstream from the city below the Fremont treatment plant and is in no way comparable to our station S-10. Low D.O. values are very common at this portion of the river. At the stations where our own D.O. measurements can be directly compared with monitor data the daily maximum and minimum values bracket our own measurements.

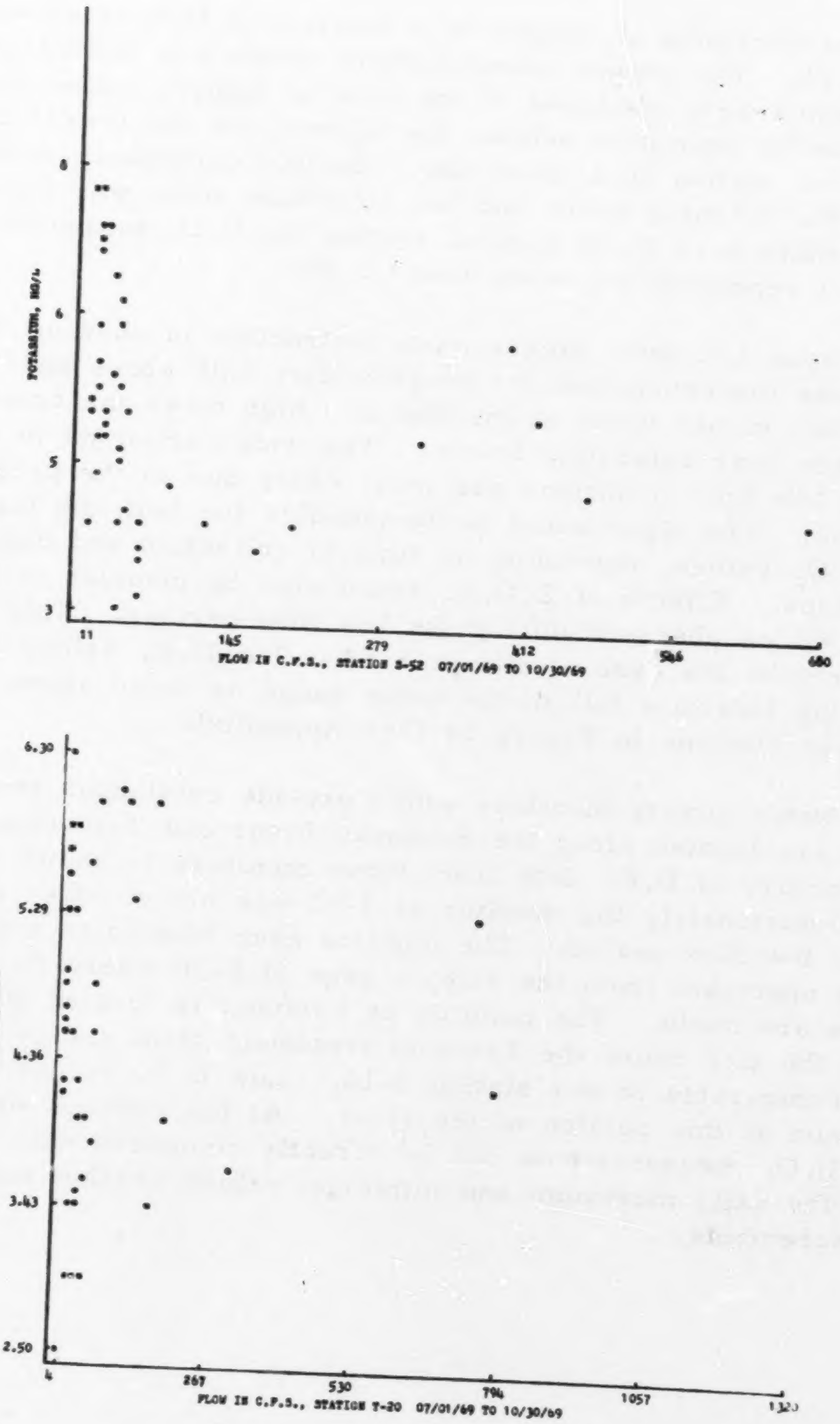


Figure 12. Relationship Between Potassium Concentration and Flow Volume

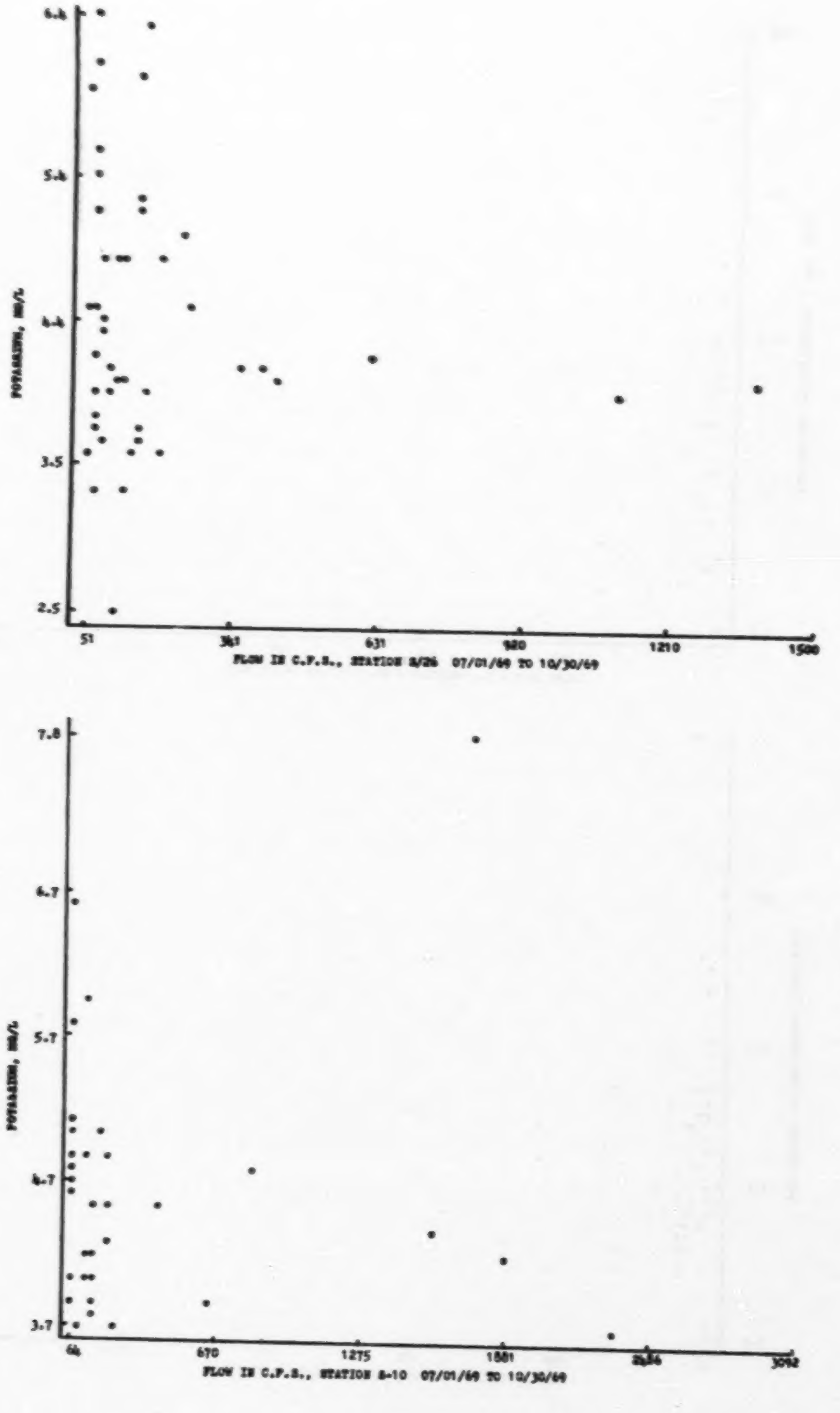


Figure 12 Continued

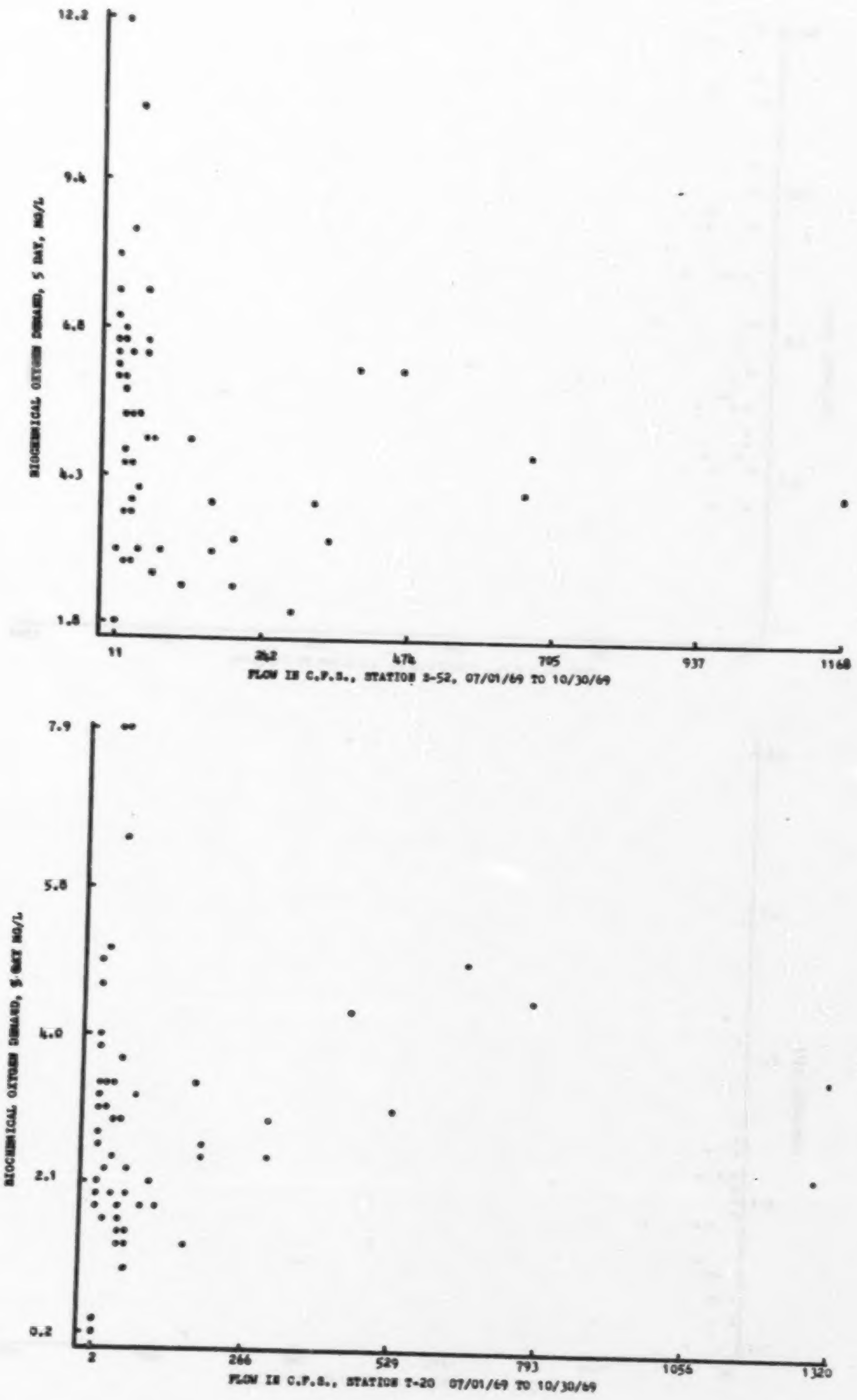


Figure 13. Relationship Between Biochemical Oxygen Demand and Flow Volume

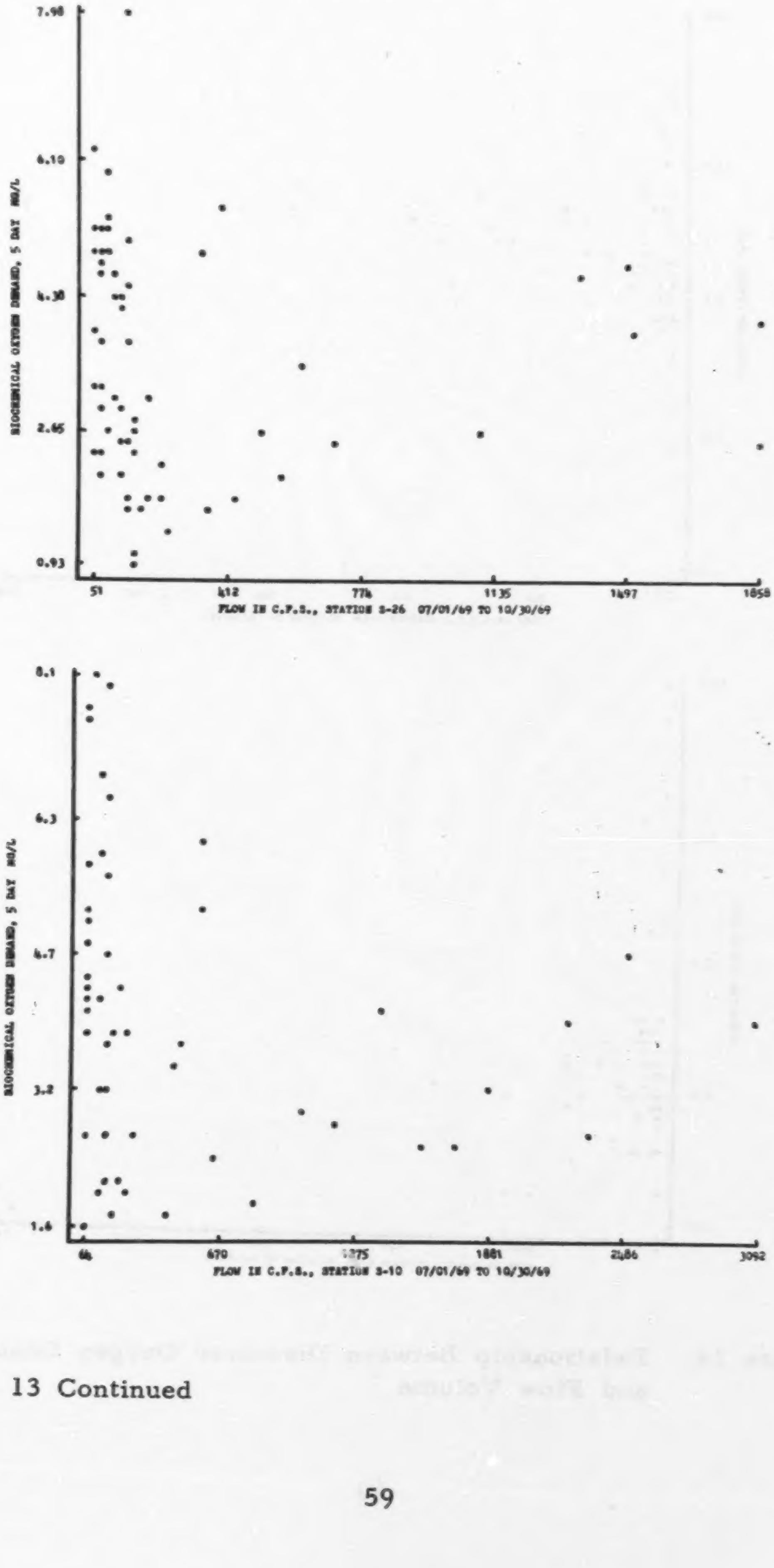


Figure 13 Continued

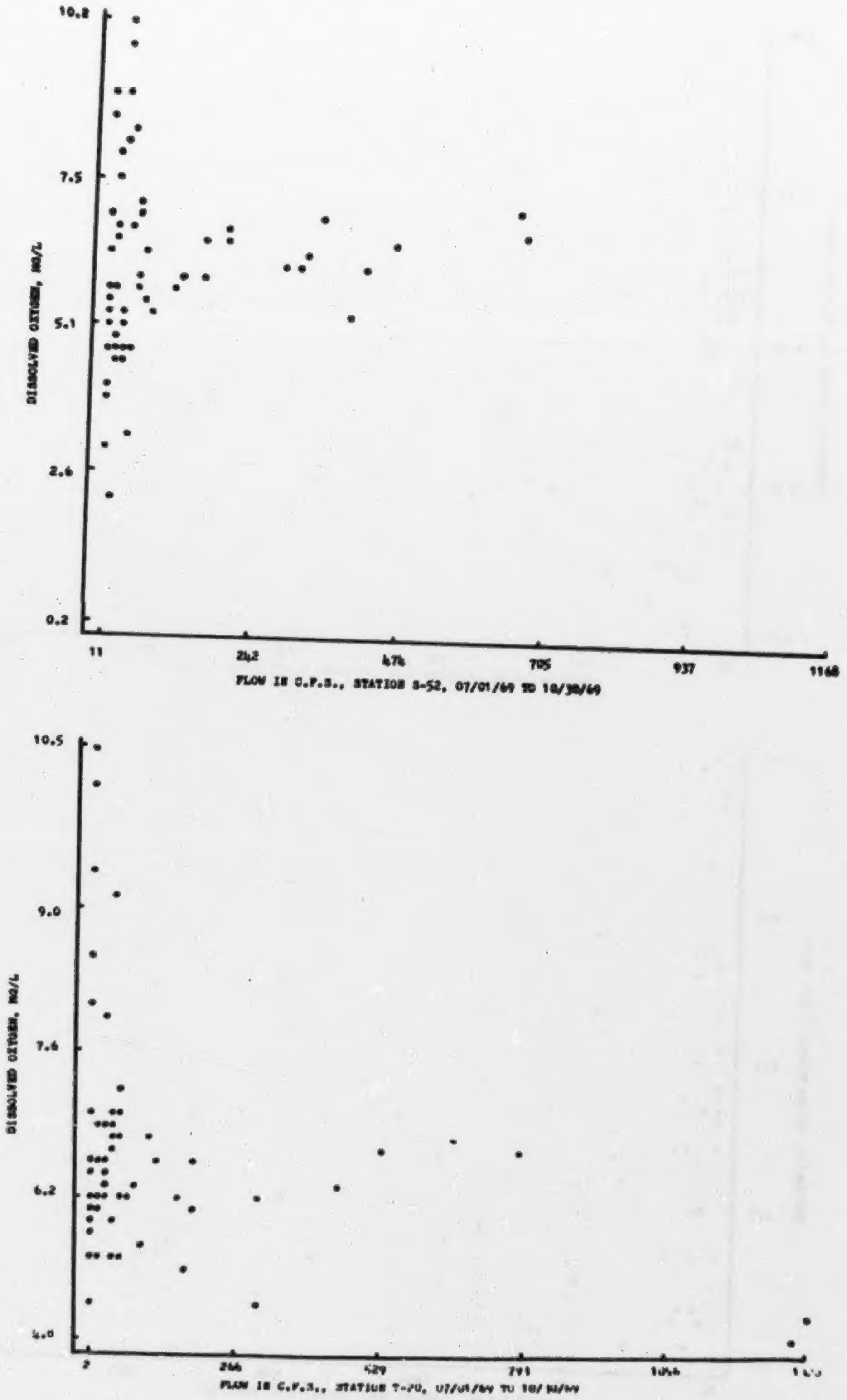


Figure 14. Relationship Between Dissolved Oxygen Concentration and Flow Volume

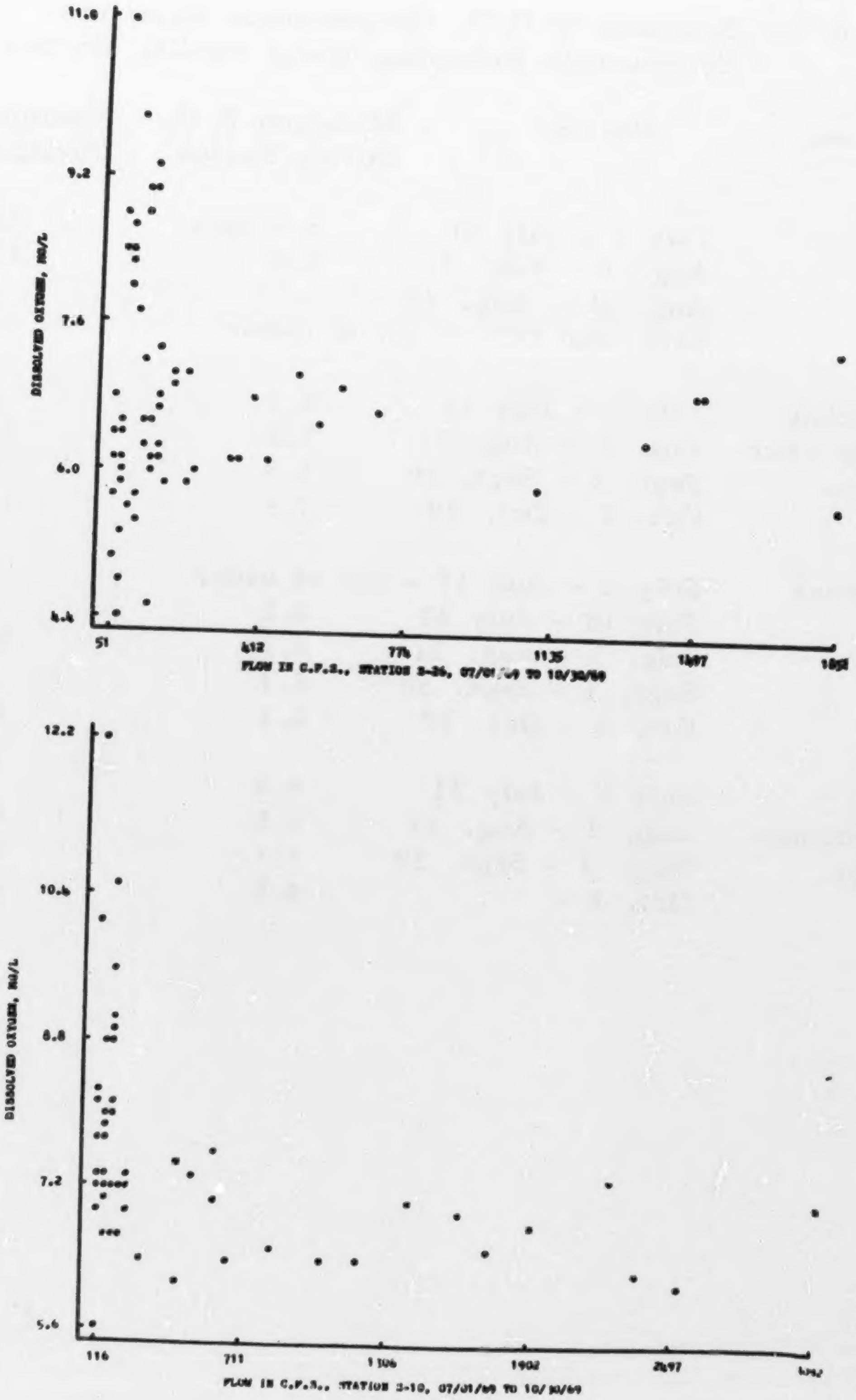


Figure 14 Continued

TABLE V. Summary of D.O. Concentration Data from Continuously Recording Water Quality Monitors

Location	Period	Minimum D.O. During Period	Maximum D.O. During Period
S-52	July 1 - July 31	5.0 ppm	15 ppm
	Aug. 1 - Aug. 7	3.9	15
	Aug. 15 - Aug. 27		
	Sept. and Oct. - out of order		
St. Johns Bridge near Mexico	July 1 - July 31	5.7	8.0
	Aug. 1 - Aug. 31	5.8	12.2
	Sept. 1 - Sept. 30	4.9	8.9
	Oct. 1 - Oct. 20	7.6	10.1
Fremont	July 1 - July 17 - out of order		
	July 18 - July 31	2.2	5.0
	Aug. 1 - Aug. 31	2.2	14.7
	Sept. 1 - Sept. 30	2.1	9.4
	Oct. 1 - Oct. 17	2.1	11.1
T-20 Tymochtee Creek	July 1 - July 31	4.4	9.2
	Aug. 1 - Aug. 31	1.5	13.3
	Sept. 1 - Sept. 30	4.1	11.2
	Oct. 1 -	4.5	12.0

SECTION IX

EXTRAPOLATION OF DATA TO MORE SEVERE LOW FLOW CONDITIONS

As pointed out in Section VII, the lowest flows which were observed during this study are 3 to 4 times greater than the 2-year frequency, 7-day duration low flows. Although it would be very useful to have direct measurements of conditions that occur during such low flows, it is possible to predict conditions based on the data and interpretations presented earlier.

As the graphs shown in Figures 4-14 were prepared, the line marking the Y-axis was offset from the lowest value on the X-axis so that the lowest values of flow would not fall on the line. Given the arithmetic scale of flow values on the X-axis, the space between the lowest flow value listed and the line marking the Y-axis is more than enough to include the lowest flows. In other words, extrapolating the graphs to the left as far as the line marking the Y-axis is more than sufficient to reach the lowest flow values.

Background Chemicals

For the background chemicals such as fluoride, sodium, magnesium and calcium, the concentration versus flow graphs (Figures 5-8) show a clustering of points in the low flow range and considerable variation in concentration at these low flow values. Within the cluster of points at the low flow range there is no pronounced trend toward higher concentrations at lower flows.

To confirm this we have replotted the graphs on an expanded scale in low flow range. The results shown in Figure 15 for fluoride, sodium, calcium and magnesium at station S-26 are typical of those at all of the stations. Only in the case of fluoride is there an apparent trend toward higher concentrations at lower flows within the low flow range. As mentioned earlier, this probably results from the input of fluorides from domestic sources.

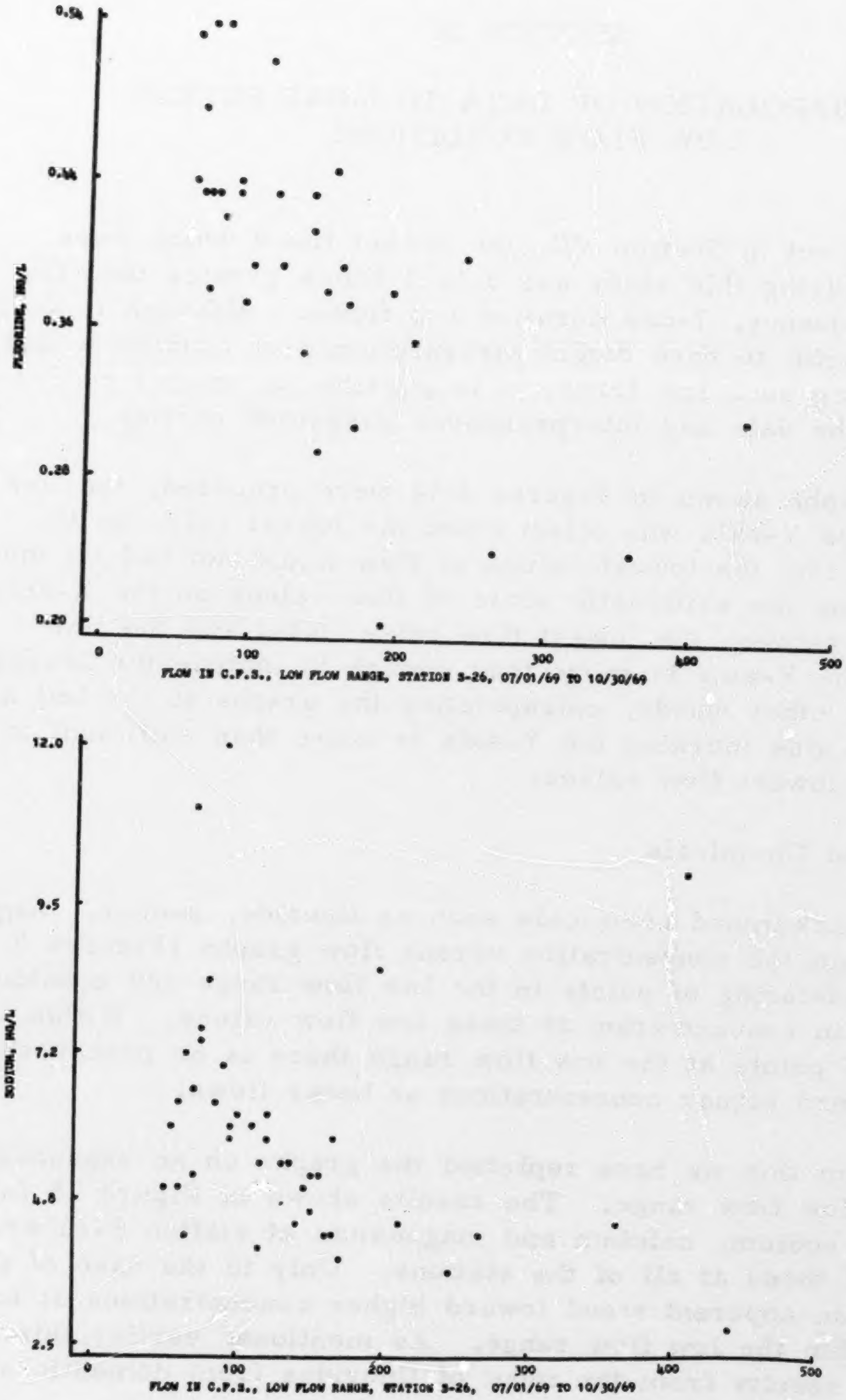


Figure 15. Concentration-Flow Relationships for Fluoride, Sodium, Calcium and Magnesium Under Low Flow Conditions

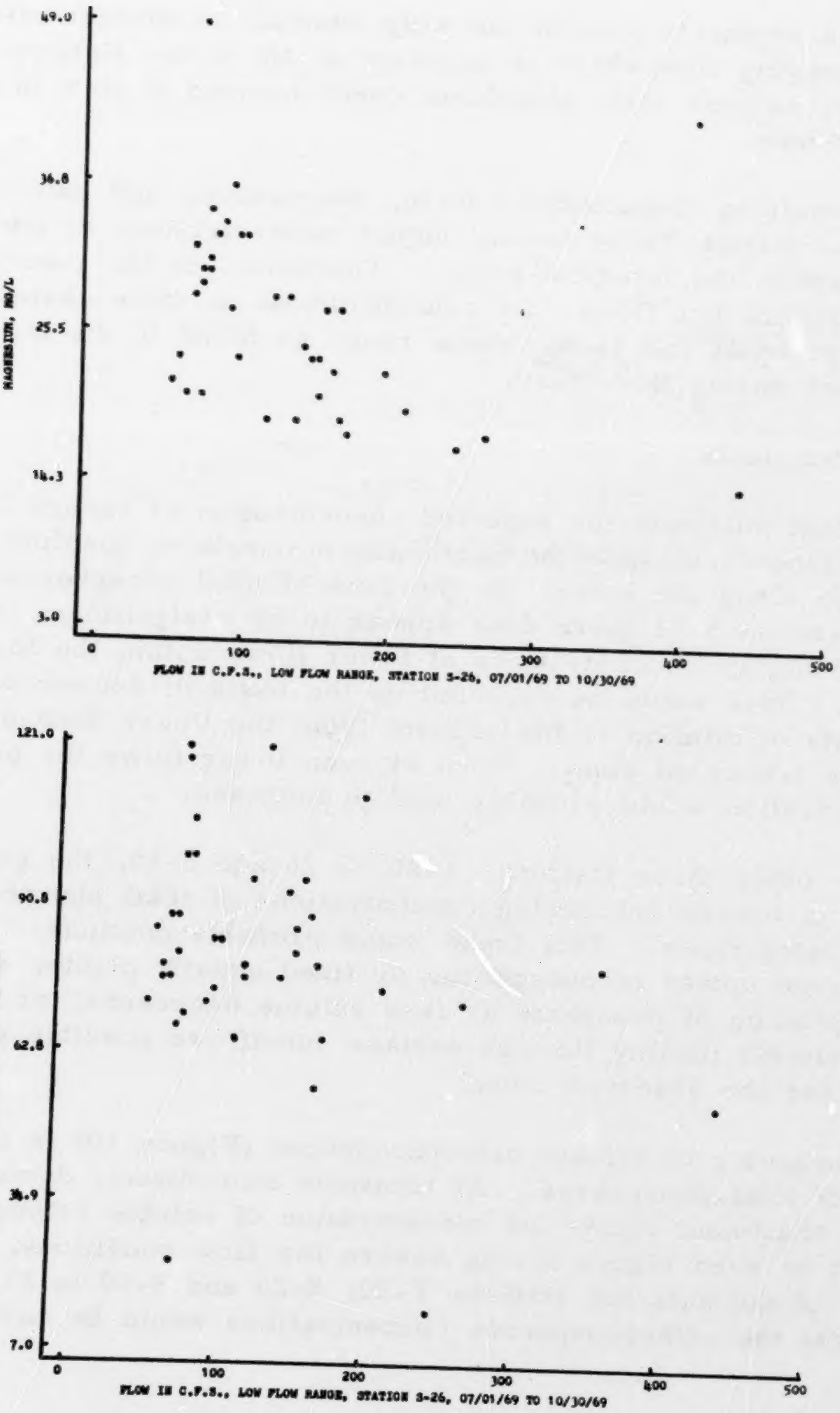


Figure 15 Continued

Fluoride seems to provide the only example of dilution effects accompanying flow which is apparent at all of the stations. Possibly various toxic chemicals could respond to flow in a similar way.

The remaining chemicals--sodium, magnesium, and calcium--show no definite trend toward higher concentrations at lower flows within the low flow range. Therefore, in the event of more severe low flows, the concentrations of these chemicals would probably fall in the same range as found in the low flows observed during this study.

Plant Nutrients

For plant nutrients the expected concentration at severe low flows depends on both the particular nutrients in question and the location along the river. In the case of total phosphorus (Figure 9) at station S-52 there does appear to be a significant trend toward higher concentrations at lower flows within the low flow range. This would be expected on the basis of decreasing amounts of dilution of the effluent from the Upper Sandusky sewage treatment plant. Thus at even lower flows the phosphorus concentration would probably tend to increase.

At the other three stations, T-20, S-26 and S-10, the general trend is toward decreasing concentrations of total phosphorus with decreasing flows. This trend would probably continue. Either increased uptake of phosphorus by fixed aquatic plants, chemical precipitation of phosphate as flow volume decreases, or decreased agricultural loading through surface runoff are possible explanations for the observed trend.

The behavior of soluble orthophosphorus (Figure 10) is similar to that of total phosphorus. At locations immediately downstream from treatment plants the concentration of soluble orthophosphorus would be even higher during severe low flow conditions. Extrapolations of the data for stations T-20, S-26 and S-10 in Figure 10 suggest the orthophosphorus concentrations would be variable and in the same range as observed during this study. No trend toward higher concentrations at lower flows is apparent.

For nitrate-nitrogen and potassium (Figures 11 & 12), trends within the low flow range are generally lacking. Possibly under severe low flow conditions the same wide range of concentrations would be found as were found during the low flows in this study. If agricultural surface runoff and/or drain tile effluents are the major determinants of the concentration of these materials, then under severe low flow it is possible that the concentration of these materials would drop.

Biochemical Oxygen Demand and Dissolved Oxygen

As for B.O.D. conditions during serious low flow periods extrapolations of the graphs in Figure 13 indicate merely that a wide range of B.O.D. values could be expected. Probably at station S-52 under serious low flow conditions the B.O.D. would increase but this depends in part on how changing flow rates affect the position of the D.O. sag. Table IV shows that even at low flows there is little increase in B.O.D. below the Tiffin sewage treatment plant.

All in all, the B.O.D. values in the areas of the river under study are not excessively high and probably would not become so under serious low flow conditions unless they were associated with algal blooms, combined sewer overflows or bypasses. We have data associated with other investigations that show high B.O.D. values are problems below both Fremont and Bucyrus.

In the case of oxygen, extrapolations of the graphs in Figure 14 would indicate that wider extremes in the D.O. can be anticipated during periods of lower flows. Confirmation of this will be possible upon publication of the water quality monitor data during the low flow periods which occurred during the late summer and fall of 1970.

As mentioned in the preceding section, along most sections of the river the low oxygen levels are more likely to be caused by algal respiration than by B.O.D. loading from sewage treatment plants. Apart from the nutrient considerations which have been discussed earlier, there is a basis for anticipating much more algal growth during severe low flow conditions than what occurred during this study. The basis is that as the flow decreases the length of time it takes for water to move through the stream increases. The increases in time of travel as flow decreases can probably be very large. In a flow augmentation study on the Scioto River information is presented which illustrates this effect.[9] Some of these data are summarized in Table VI. These calculations were carried out for projected critical flows and did not extend to low flows. If the trend present for the various critical flows is extended to low flows, then one could expect 2- to 4-fold increases in the time of travel in going from the 80% flow to the low flows.

A limited number of dye tracer studies were done on the Sandusky River by Heidelberg students during the summer of 1970.[10] The times of travel which they observed in a 0.56 mile section of the river immediately downstream from the Bucyrus Treatment Plant were 3.9 hours at 13 C.F.S., 5.05 hours at 9 C.F.S. and 6.25 hours at 3.5 C.F.S. These data support the trend of longer travel times at lower flows.

An additional consideration which leads to the prediction of substantially longer travel times as flow decreases is that in areas of the river where water is backed up by low head dams the volume of water behind the dams will probably not change greatly during low flow conditions. Certainly the volume of water behind the dam will not be proportional to the flow. If the volume were constant, then the time of travel would be inversely proportional to the flow. Given the difference in flow between 80% levels and 2-year frequency, 7-day duration flows, the effect could lead to 2- to 3-fold increases in time of travel between these two flow levels. Several such low head dams are present in the study area.

The original study plan called for extensive time of travel studies in the Sandusky using dye tracers. During the first year we did become familiar with the techniques but did not have the opportunity to actually undertake such studies in the river.

The increased time of travel probably constitutes the most important change in the river in going from 80% flow to severe low flow

TABLE VI. Relationships Between Time of Travel and Flow in the Scioto River*

Flow Regime C.F.S.	Cumulative Time of Passage for Travel of 400,000 ft. below Columbus
300	8.4 days
200	11.5 days
134	16.8 days
54 (80% flow level)	No prediction
10 (frequently observed to flow)	No prediction

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* Data from Report on Waste Treatment and Low Flow Augmentation Study of the Lower Scioto River.

conditions. If algal bloom development follows an exponential growth curve, then even slight increases in time of travel could greatly increase the algal concentration at a given site. The extent to which algal growth is time limited as opposed to nutrient limited is a very important question in predicting augmentation effects, and the data currently available do not allow evaluation or even prediction of the relative importance of the two effects. Other limiting factors such as temperature and light would also have to be considered.

The preceding discussion assumes that phytoplankton comprise the significant plant community responsible for the diurnal oxygen fluctuations. If attached algae are the major factors, then neither the time of passage changes nor nutrient concentrations are likely to be as important factors in affecting the extent of algal growth as these factors would be for phytoplankton growth. However, the volume of water present in the stream would still greatly influence the extent of diurnal oxygen fluctuations. As the flow volume decreases, given rates of respiration and photosynthesis would cause greater fluctuations in oxygen concentration. Possibly the flow volume would also affect the light intensity reaching algae attached to the bottom of the stream.

Whether the algae that cause diurnal fluctuations are planktonic or attached, conditions during severe low flows are such that greater 0_2 fluctuations would be expected. These fluctuations would include many instances where the oxygen level would fall well below the acceptable levels according to state water quality standards.

SECTION X

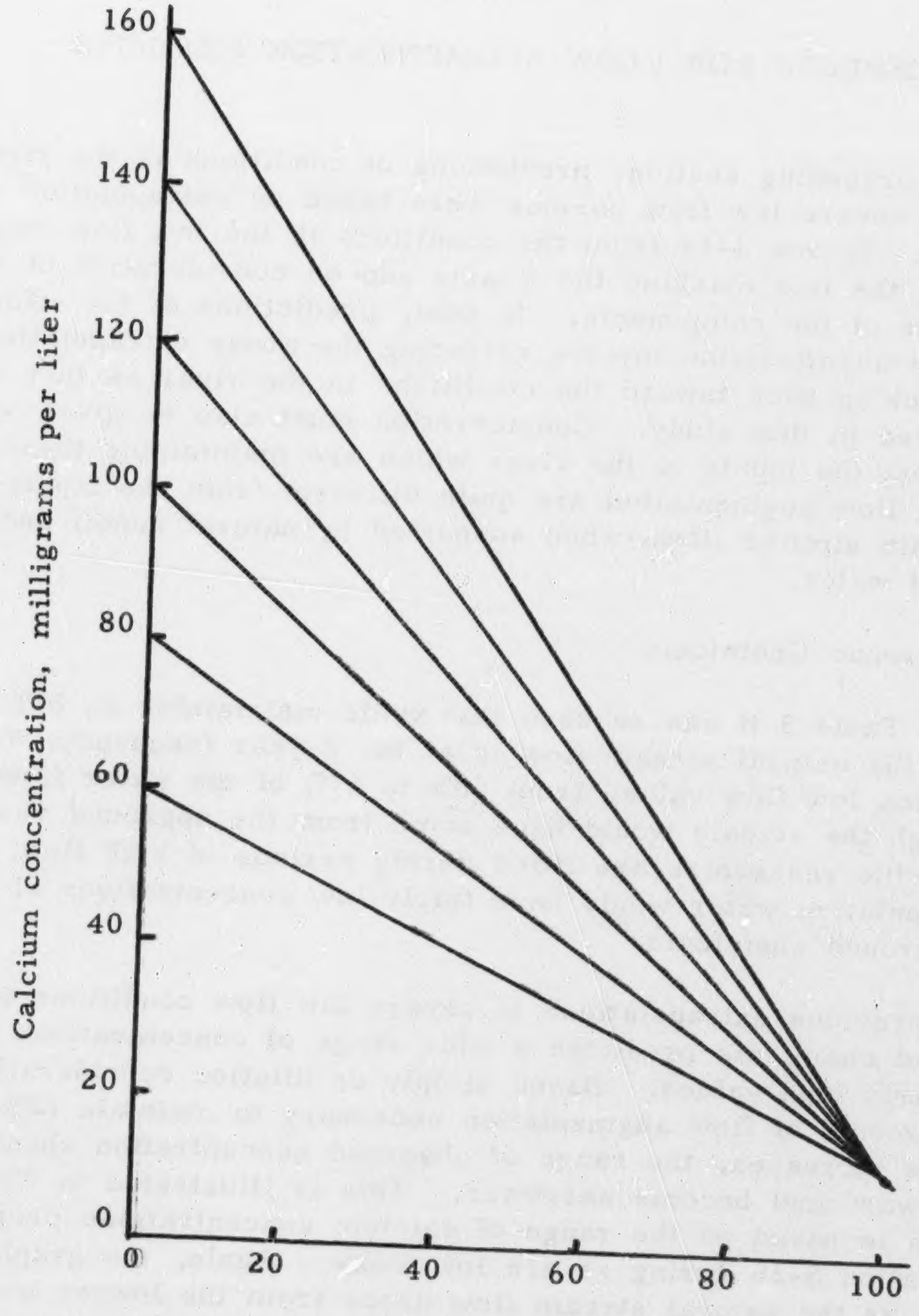
PROSPECTS FOR FLOW AUGMENTATION BENEFITS

In the preceding section, predictions of conditions in the river during severe low flow periods were based on extrapolation of data in Figures 4-14 from the conditions in the low flow range toward the line marking the Y-axis and on consideration of input sources of the components. In part, predictions of the effects of flow augmentation involve retracing the above extrapolations and looking back toward the conditions in the river as they were observed in this study. Consideration must also be given to the fact that the inputs to the river which are maintaining these flows during flow augmentation are quite different from the inputs which maintain similar flows when supported by natural runoff and/or ground water.

Background Chemicals

From Table 3 it can be seen that while maintaining an 80% flow when the natural stream flow is at the 2-year frequency, 7-day duration low flow value, from 58% to 67% of the water flowing through the stream would have come from the upground reservoir. Since the reservoirs are filled during periods of high flow, the augmentation water would have fairly low concentrations of the background chemicals.

The previous extrapolations to severe low flow conditions for background chemicals predicted a wide range of concentrations centered at fairly high values. Based simply on dilution considerations, as the amount of flow augmentation necessary to maintain 80% flow levels increases, the range of observed concentration should shift downward and become narrower. This is illustrated in Figure 16 which is based on the range of calcium concentrations projected at station S-26 during severe low flows. Again, the graph assumes that, as the natural stream flow drops from the lowest levels observed to severe low flow conditions, the range and distribution of calcium concentrations will show no significant change. Dilution calculations were made for natural stream flow concentrations ranging from 60 to 160 mg/l. The dilution water from the



Percent of water from upground reservoir
(Assumes 10 mg/l calcium in augmentation water and constant total flow)

Figure 16. Projected Dilution Effects During Flow Augmentation

upground reservoir was assumed to have a calcium concentration of 10 mg/l. This figure is based on the calcium concentrations of Tymochtee Creek. It is assumed that the same pattern of concentration versus flow observed during the summer-fall period will hold during the winter and spring months when the reservoir will be filled. At present we have no data to support this.

Dilution calculations were made for maintaining a constant flow where the augmentation water comprises 15%, 30%, 45%, 60% and 75% of the total flow. As can be seen in the graph, as the percent of flow augmentation water increases, the range of calcium concentrations shift downward and become narrower.

The extent to which straightforward dilution calculations can be applied to the background chemicals remains to be seen. Possibly exchange of materials with the stream bottom during these relatively low flow periods (and consequently longer passage times) would prevent the transport of "low concentration" water over long distances without considerable increases in concentration. At times when low concentration water is moving down the stream both the high flow volume and diminished travel time could mask exchanges with the river bed. Concentration by evaporation in the stream could also interfere with straightforward dilution calculations.

In the absence of information on stream bed exchange and evaporative concentration, the "first approximation" prediction for effects of flow augmentation on the background group of chemicals is that effects similar in principle to those outlined in Figure 16 for calcium would occur. The significance of this particular effect in terms of the overall response of the river to flow augmentation is difficult to assess. As with all evaluation of flow augmentation effects, one must consider not only the conditions which have been produced but also the conditions which have been prevented. The effect of apparently small changes in concentration of some chemical from low flow to augmented flow conditions could be greatly magnified by the altered time of travel conditions which accompany augmented flow.

Plant Nutrients

It is more difficult to predict the effects of flow augmentation on the concentrations of total phosphorus and other plant nutrients. The relationship between total phosphorus concentration and flow during the period of this study indicates that at high flows the total phosphorus concentration tends to be high. At station T-20 these high concentrations persist to fairly low flows and, if similar conditions prevail in early spring when the reservoir is to be filled, the initial phosphate concentrations could be rather high. If high phosphorus concentrations are present initially, then the fate within the reservoir of these concentrations during spring and summer would be of interest, especially to the extent that the high total phosphorus enters in combination with silt. Also, the absence of thermal stratification in upground reservoirs could tend to keep the nutrients circulating within the entire volume of the reservoirs. Although it is not a foregone conclusion, for purposes of further analysis, let us assume that the water for augmentation does have a total phosphorus concentration equal to 0.1 mg per liter which is the next to lowest value shown in Figure 9 for station T-20.

The effects of flow augmentation on the concentrations of chemicals in the river depend to a great extent on the input sources of the chemical. If the substance is carried to the river as part of the surface runoff or ground water, then the fluxes of the material into the river will probably decrease as the volume of runoff and/or ground water decreases. This assumes that there is not a compensating increase in concentration of the material as the flow volume decreases. These are the kinds of substances for which the calculations of Figure 16 are applicable. For them, as the percent of augmentation increases, their concentration will decrease depending on the relative concentrations of the natural stream flow and the augmentation water.

If the source of the material is primarily from a town or industry which provides a relatively constant input of the material independent of stream flow, the results will be different. Maintaining flow by increasing amounts of augmentation as natural stream flow decreases will result in the concentration of the material in the receiving stream remaining constant rather than decreasing.

In the case of phosphorus, domestic sewage treatment plants certainly constitute significant inputs to the river. These inputs provide a relatively constant flux into the river. In addition, agricultural surface runoff also contributes significant inputs into the river. These fluxes from agricultural runoff vary tremendously with the amount of runoff. This double source of phosphate greatly complicates the job of predicting the consequences of varying amounts of flow augmentation on phosphorus concentrations. Added to this is the problem of uptake of phosphorus by fixed plants and/or precipitation of phosphates along the stream; predictions thus become even more difficult.

Analyses of the patterns of concentration versus flow for total phosphorus (Figure 9) indicate that at locations immediately downstream from sewage treatment plants the predominant loading at low flows is from the treatment plant. This is also apparent from the data in Table IV. At these locations, as the amounts of flow augmentation increase in maintaining 80% flow, the phosphorus concentrations will probably remain constant and, consequently, the values would be similar to those observed at these locations during the low flow periods of this study.

The graphs for stations T-20, S-26 and S-10 indicate that phosphorus concentrations decrease as flows decrease. Under these conditions the phosphate fluxes are decreasing rapidly with decreasing flow and, consequently, dilution effects by flow augmentation water would be very large. For these three stations the lowest phosphate concentrations during the year would occur during the 20% of the time that flow was being augmented. The data indicate that at all other times the phosphorus concentration would be larger than during periods of augmentation.

In summary, with flow augmentation the concentration of total phosphorus at locations immediately downstream from treatment plants would remain at approximately the same high levels as were observed during the lowest flow levels of this study. At sites further downstream the concentration would decrease significantly as the percent of flow augmentation increases.

What flow augmentation prevents is even higher phosphate concentrations below treatment plants and moderately high phosphate concentrations at sites further downstream. Both of these would have occurred in combination with greatly increased time of travel during severe low flow periods. Thus the conditions which conspire to support serious algal blooms during severe low flow periods could be significantly alleviated by augmented flow.

The effects of augmentation on orthophosphorus would probably parallel those of total phosphorus. Given the lack of any significant trends in the concentration-flow curves for nitrates and potassium (Figures 11 & 12), predictions of flow augmentation effects will not be attempted.

Biochemical Oxygen Demand and Dissolved Oxygen

For most sections of the river within the study area the projected B.O.D. values during severe low flows were the same as those observed under the low flow conditions in this study; i.e., extremely variable but generally low. For the most part, these values probably represent "natural" B.O.D. development as opposed to the effects of outside loading (B.O.D. contained within surface runoff water is considered part of the natural B.O.D.). Since in all sections of the river except those immediately below the reservoir, the B.O.D. of the augmentation water would have reached its "natural" level, it is not possible to assume direct dilution effects on B.O.D. values in most sections of the stream. The only exception for this is in the areas immediately below sewage treatment plants. At these sites the B.O.D. values would remain at the values observed during the lowest flow periods in this study. What is prevented by flow augmentation is even higher B.O.D. values at these locations during severe low flow conditions.

Since the oxygen status of the water is closely coupled to the B.O.D. and algal concentrations, it is apparent that flow augmentation will significantly affect the oxygen condition in the stream. The conditions in the stream during flow augmentation should be similar to those found at 80% flow levels or during the lowest flows of this study. Flow augmentation effects on D.O. through dilution of B.O.D. would be limited to areas immediately below treatment plants. For the study area these effects would be much less important than the augmentation effects associated with a diminution of algal blooms.

SECTION XI

EXTENSION OF DATA TO RELATED WATER QUALITY CONSIDERATIONS

Relationship Between Material Fluxes and Flow Volumes

Although the main objective of the surveillance program was to observe the relationship between concentration of materials and flow volumes, these data also provided information on material fluxes. The data from Figures 5-12 have been transformed to material fluxes in pounds per hour and are shown in relation to flow volumes (Figures 17-24). The fluxes of the background chemicals (fluoride, sodium, magnesium, and calcium) are shown first, followed by the fluxes of the plant nutrients (total phosphorus, orthophosphorus, nitrate and potassium).

In all cases the fluxes increase markedly with flow volume. For the chemicals whose concentrations decrease with increasing flow, the magnitude of the increases in flow is sufficient to generate the large increases in fluxes which occur. The differences between the fluxes during high flows and low flows emphasize the importance of high flow periods in terms of loading of materials to downstream areas such as Lake Erie. It should be noted that the data presented in the graphs include only the July 1 through October 30, 1969 period. If the trends seen in these graphs hold on a year-round basis, then much higher fluxes would occur during the high flow periods of December through March.

The differences in fluxes between high flow periods and low flow periods are even more marked for substances where high concentrations are present during high flows; i.e., the plant nutrients. For these the loading during high flows completely dwarfs the loading at low flows. Table VII illustrates this point. The 10 highest and 10 lowest total phosphorus fluxes at stations S-10 and S-26 are listed. The data from approximately weekly collections during the winter and spring of 1970 are included. Also note that on no occasion did the flow value drop below the 80% level. The conclusion from Table VII and Figure 21 is that the fluxes

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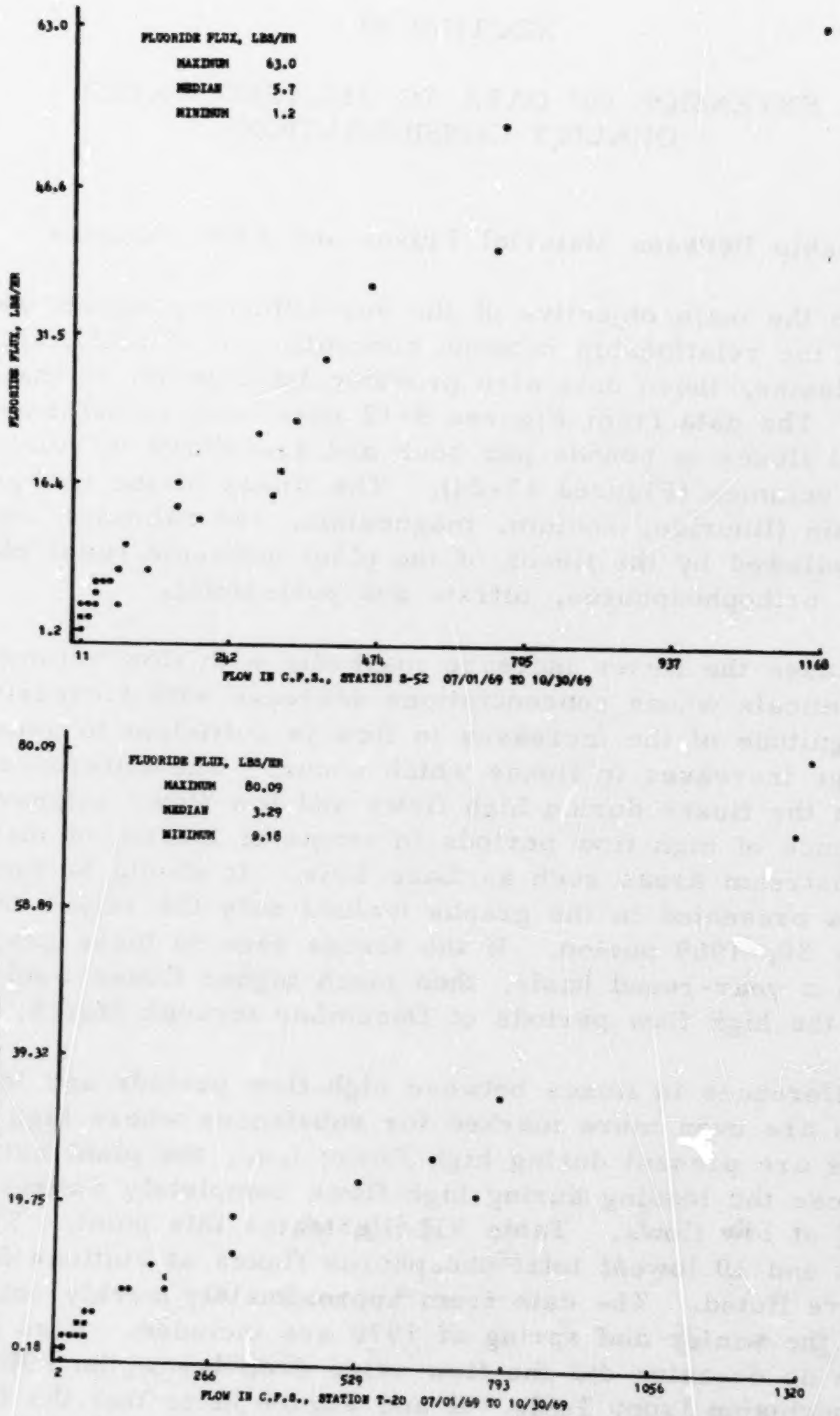


Figure 17. Relationship Between Fluoride Flux and Flow Volume

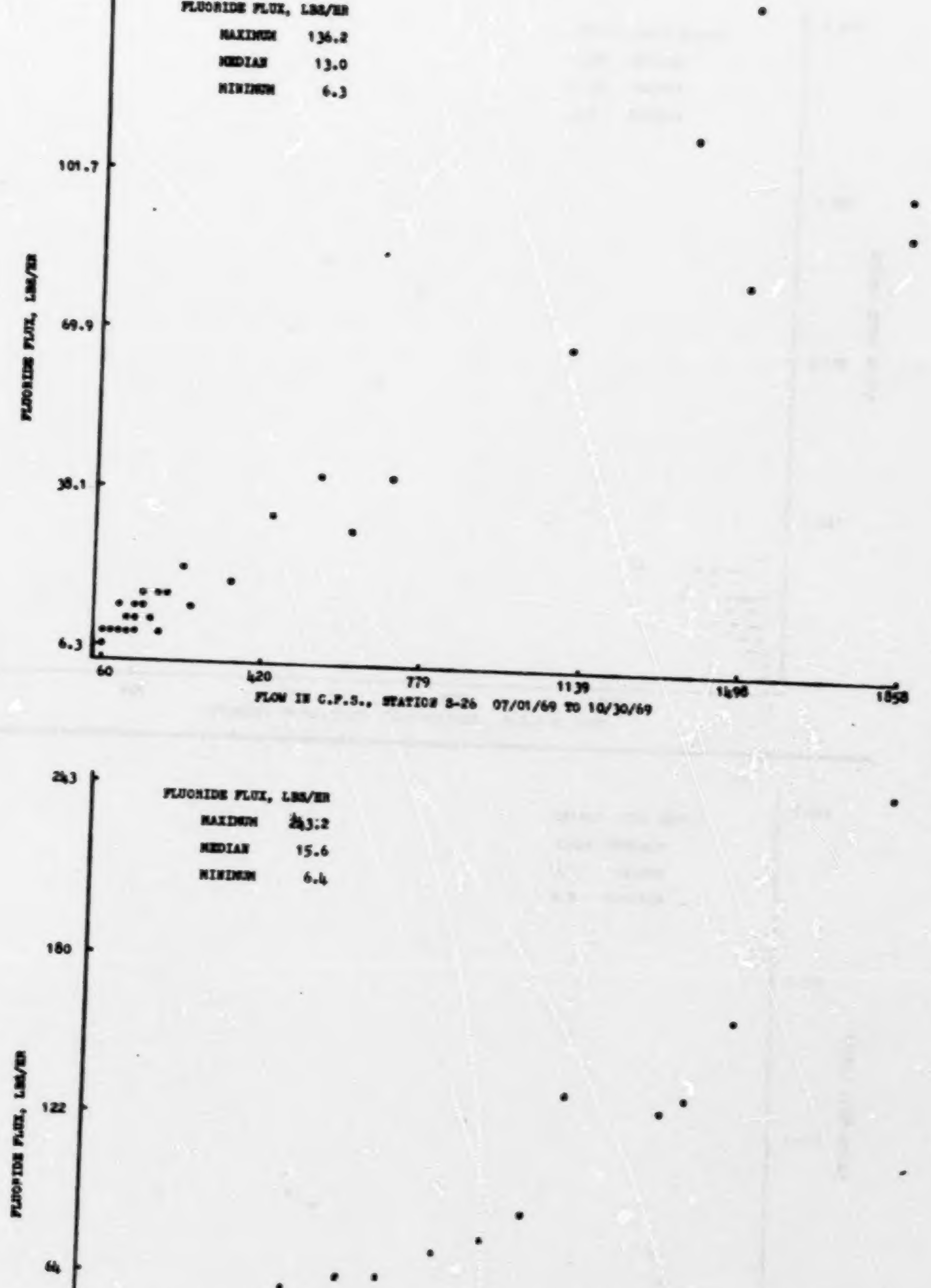


Figure 17 Continued

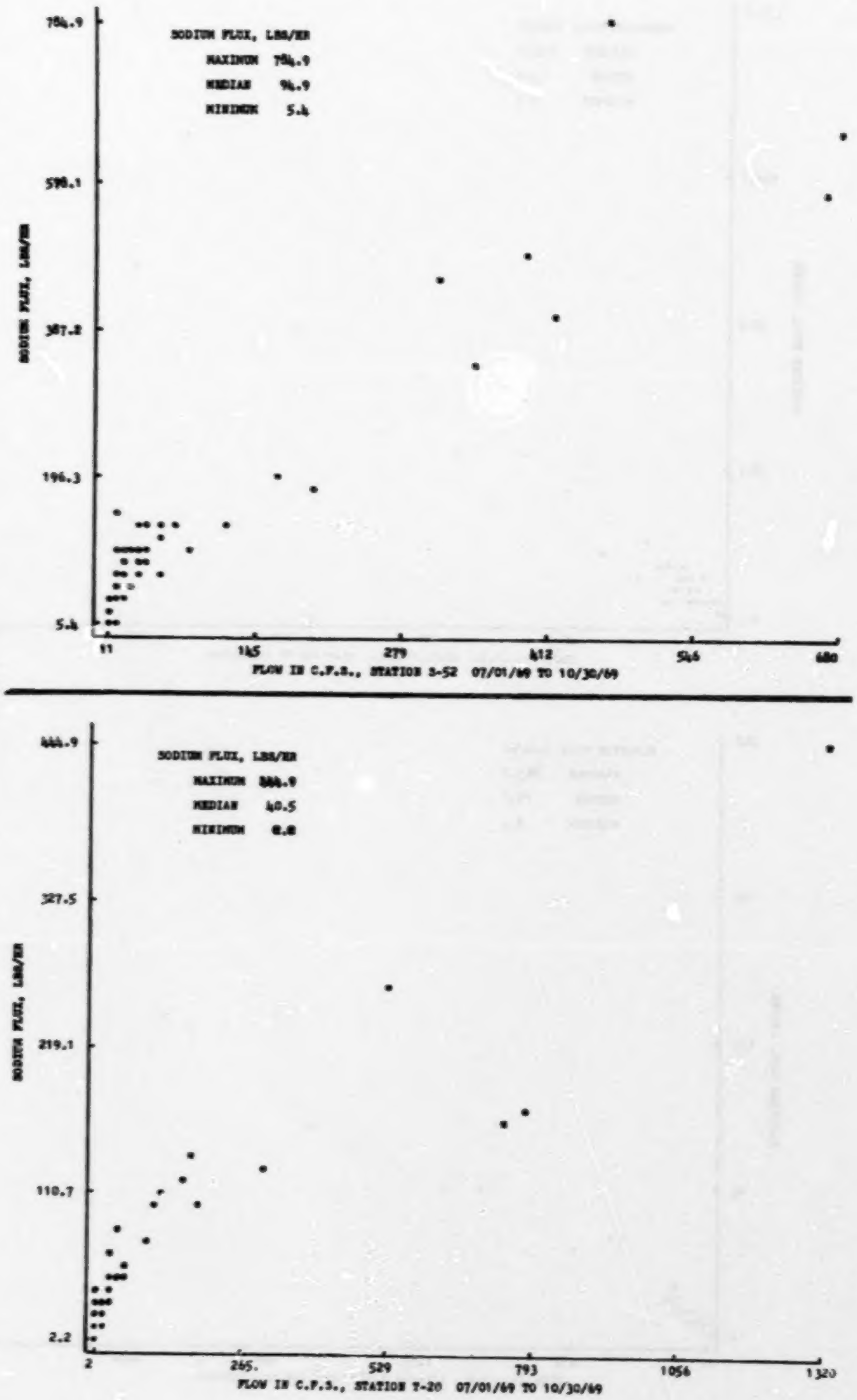


Figure 18. Relationship Between Sodium Flux and Flow Volume

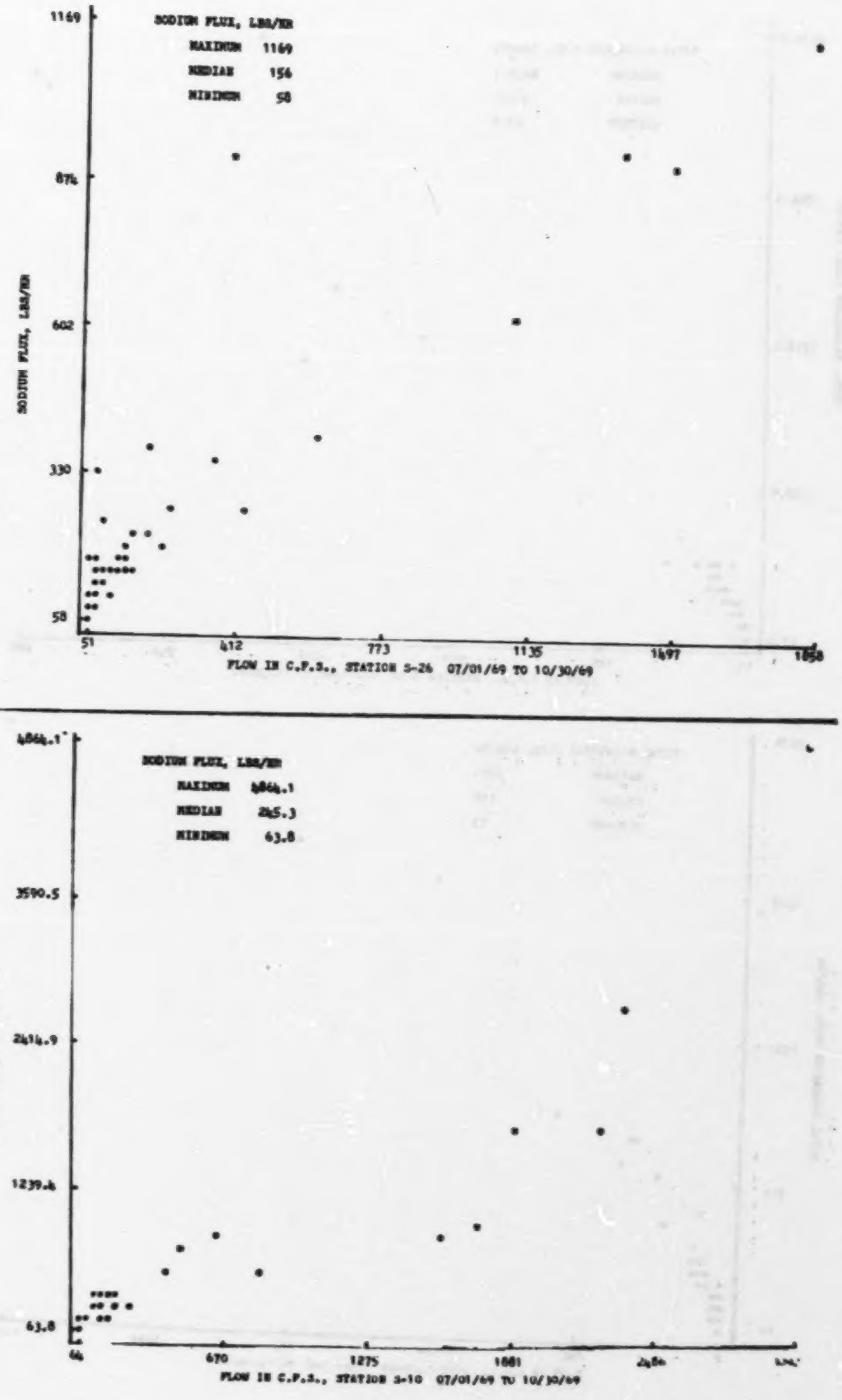


Figure 18 Continued

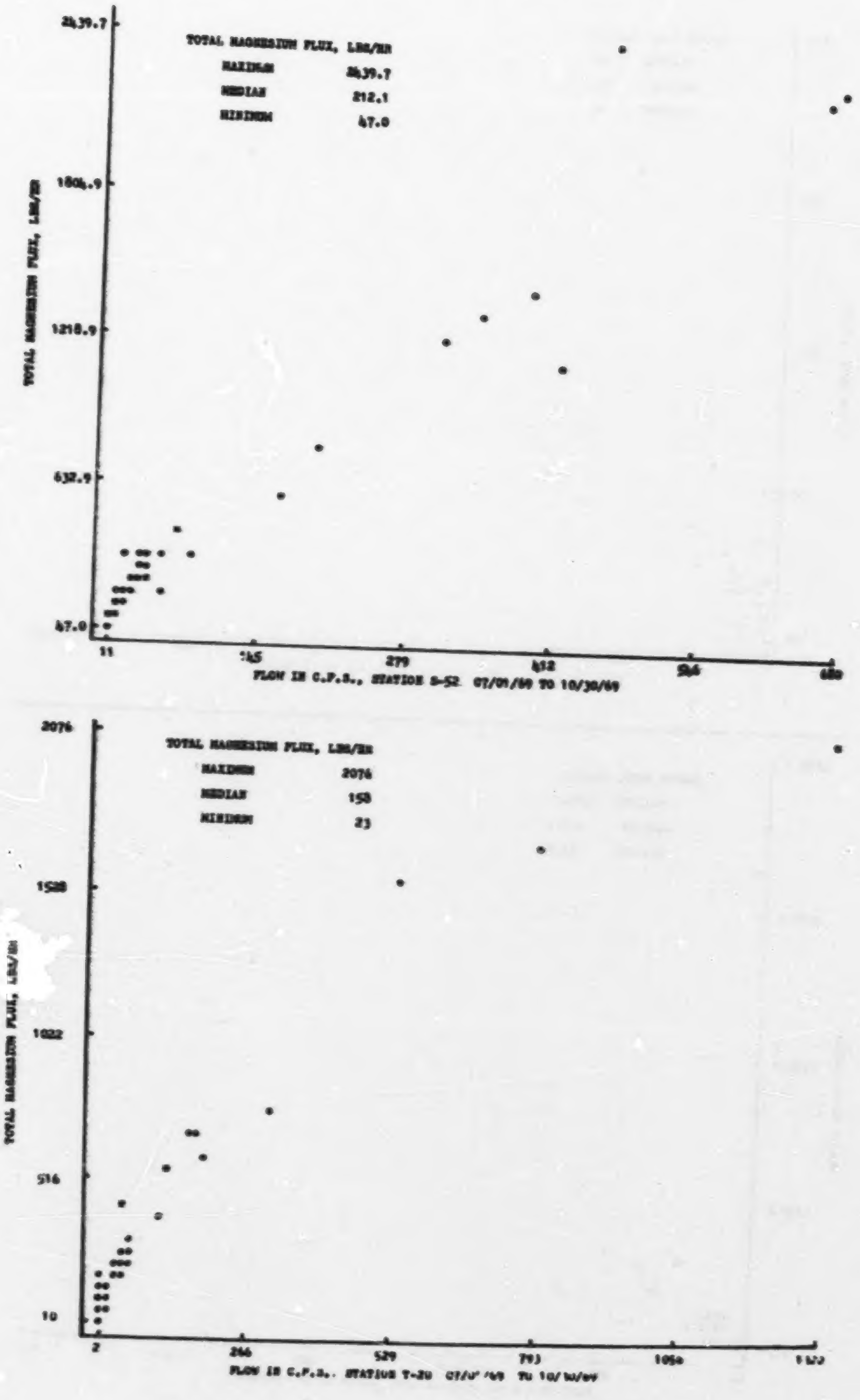


Figure 19. Relationship Between Magnesium Flux and Flow Volume

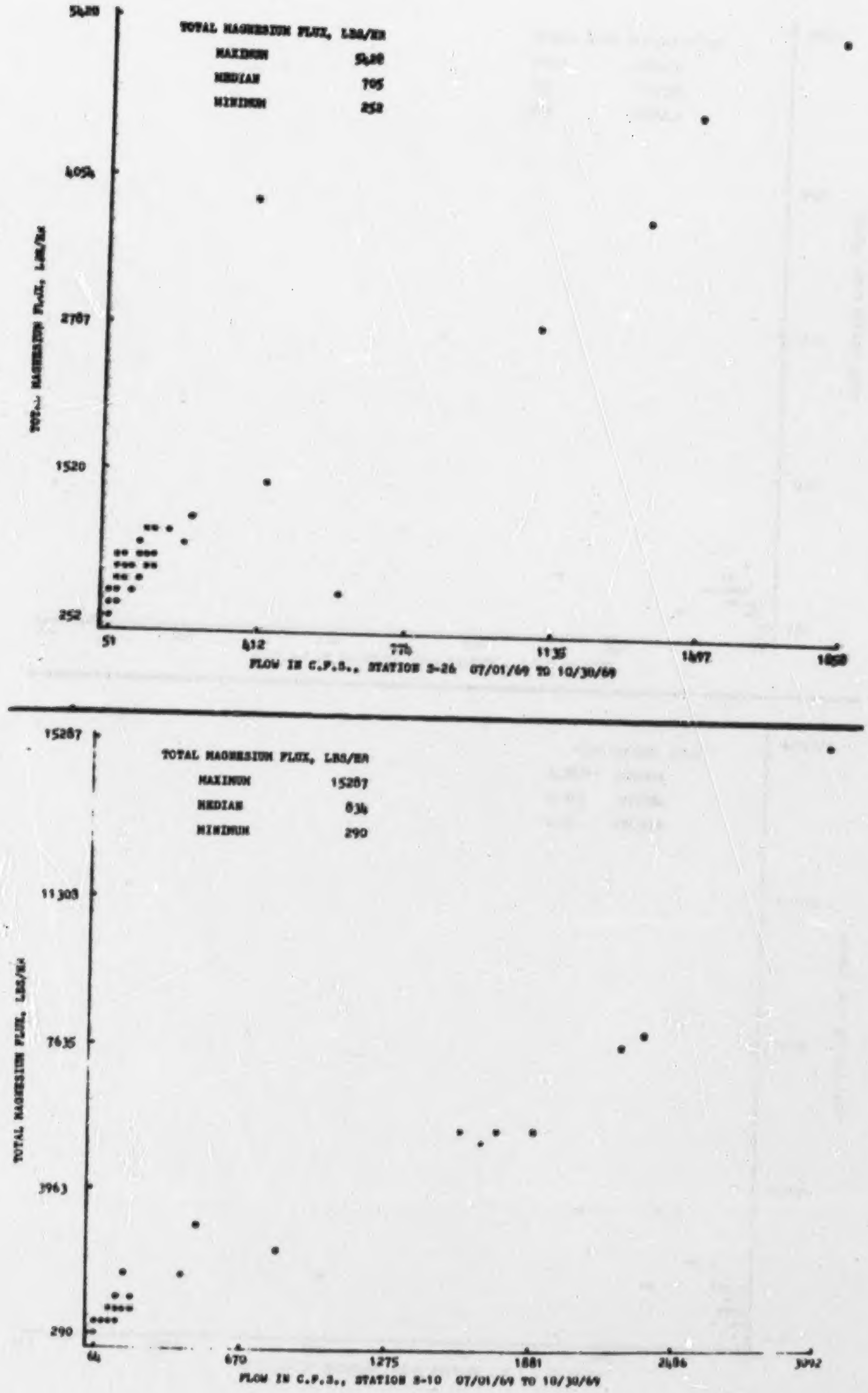


Figure 19 Continued

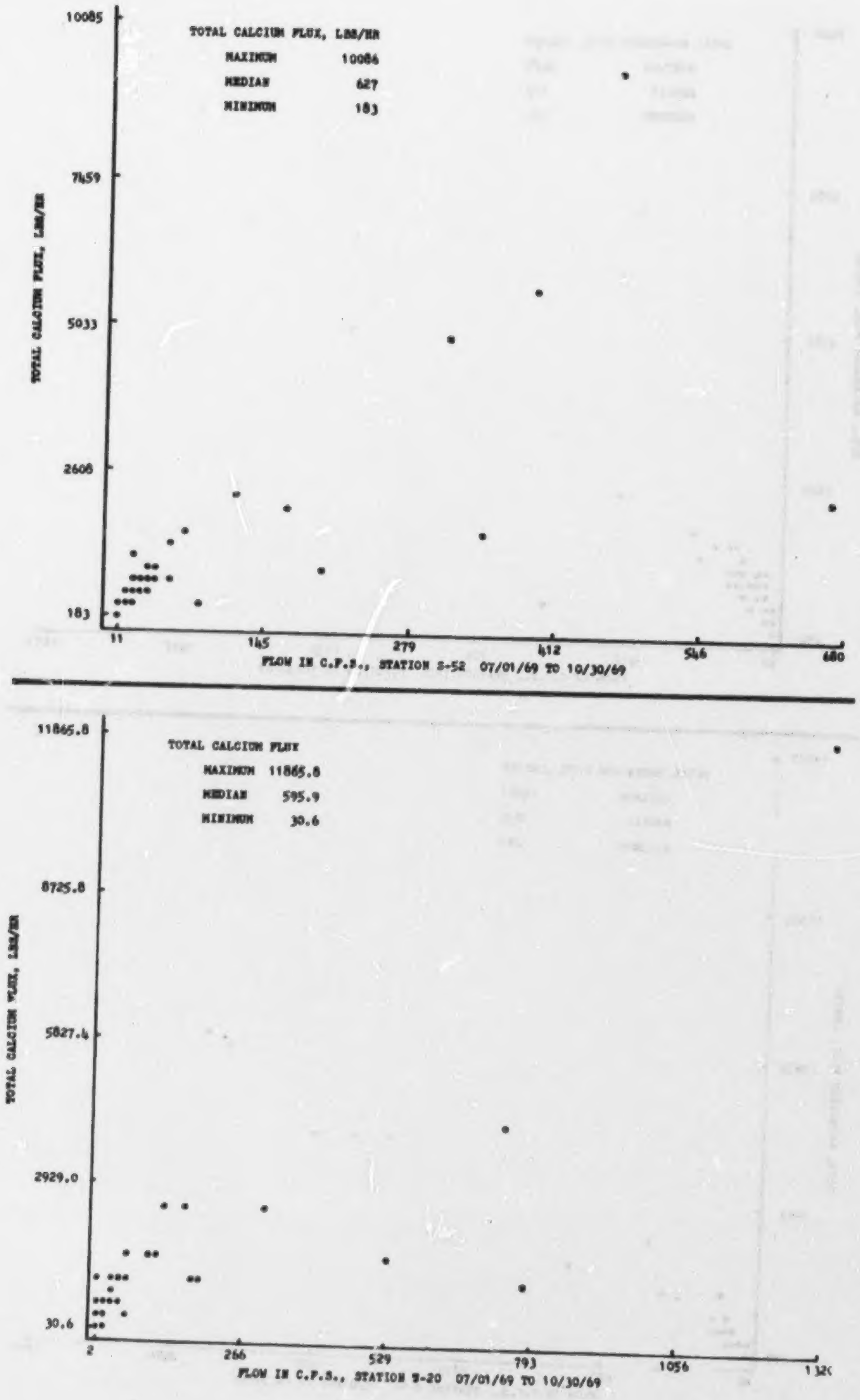
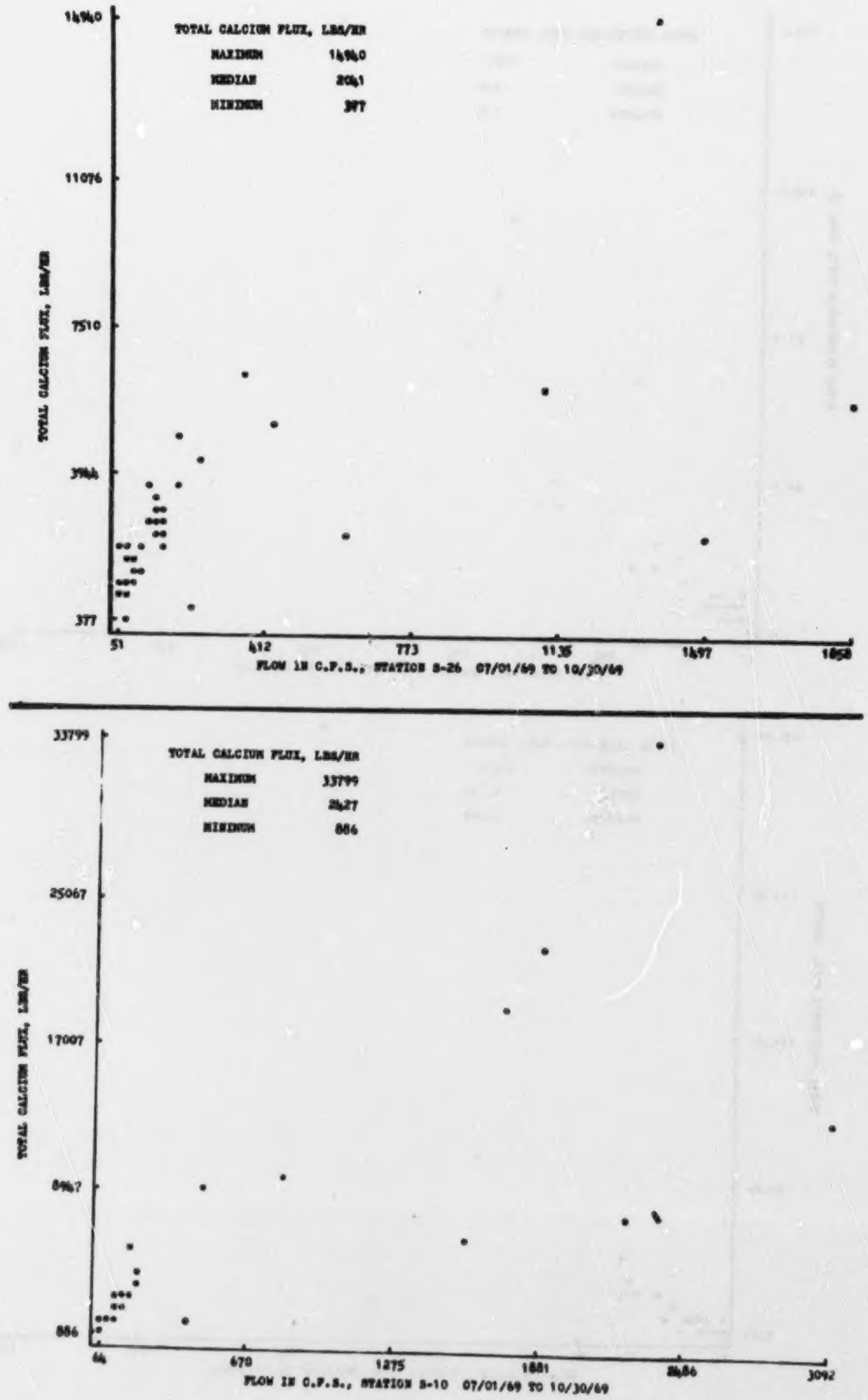


Figure 20. Relationship Between Calcium Flux and Flow Volume



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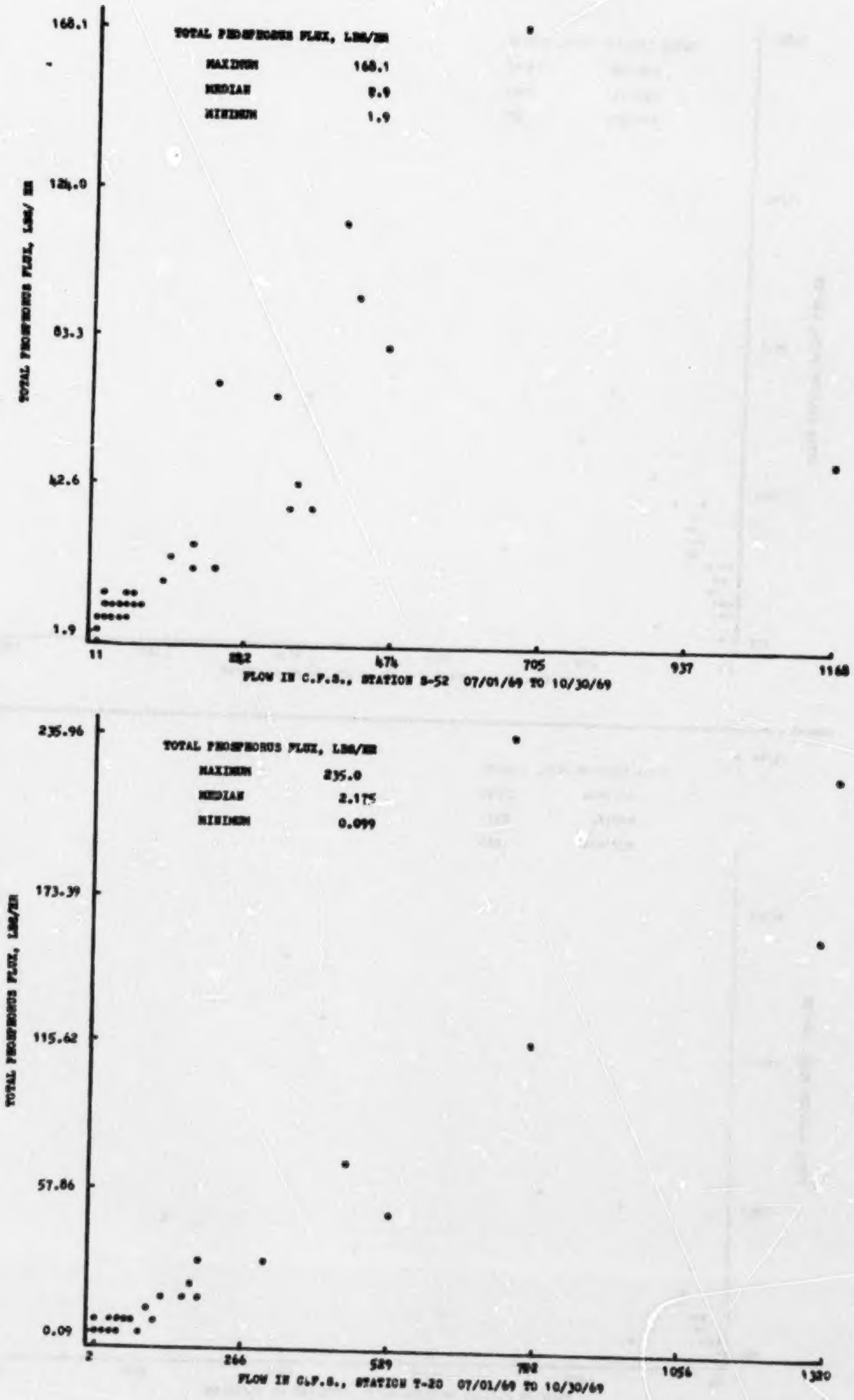
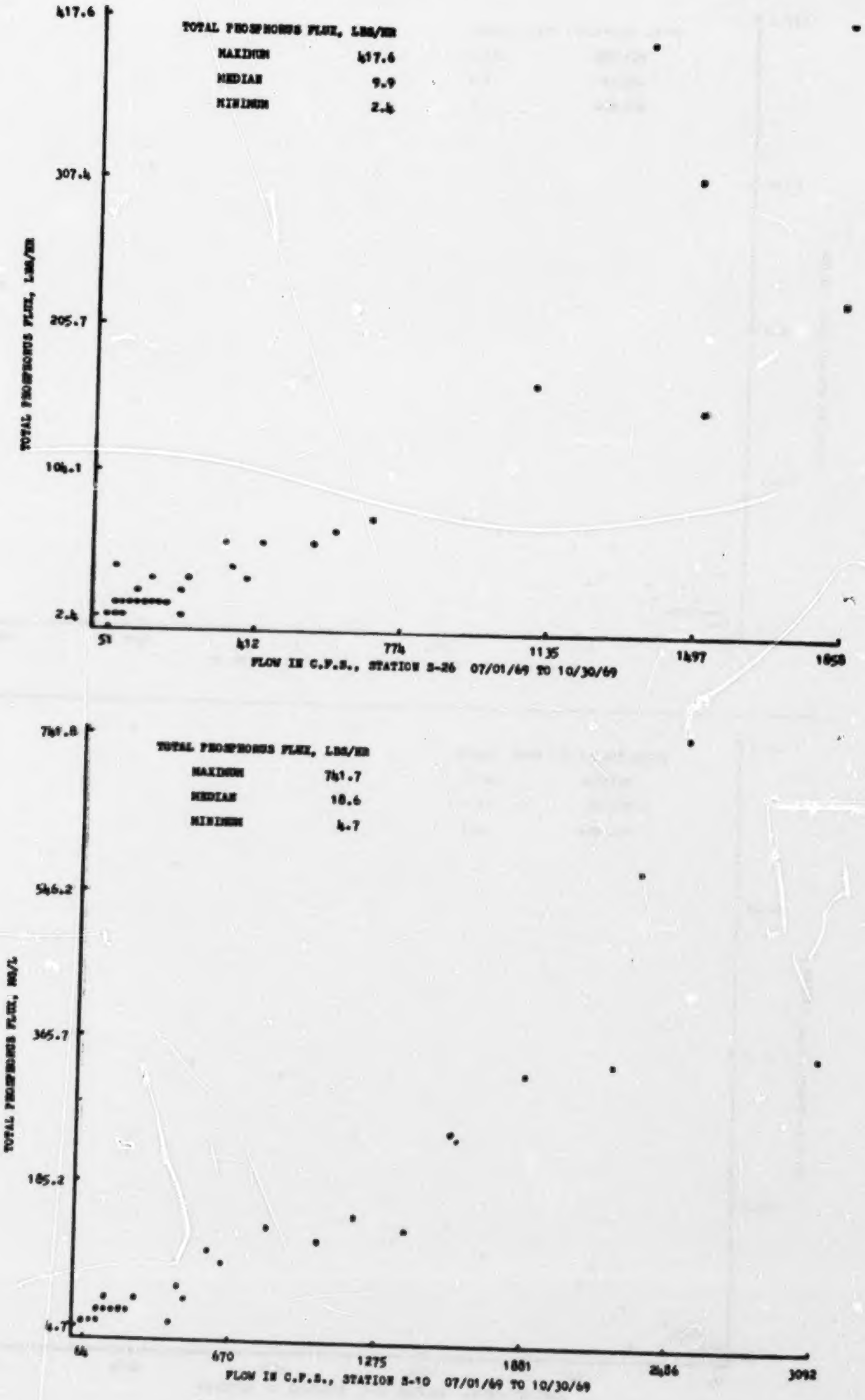


Figure 21. Relationship Between Total Phosphorus Flux and Flow Volume



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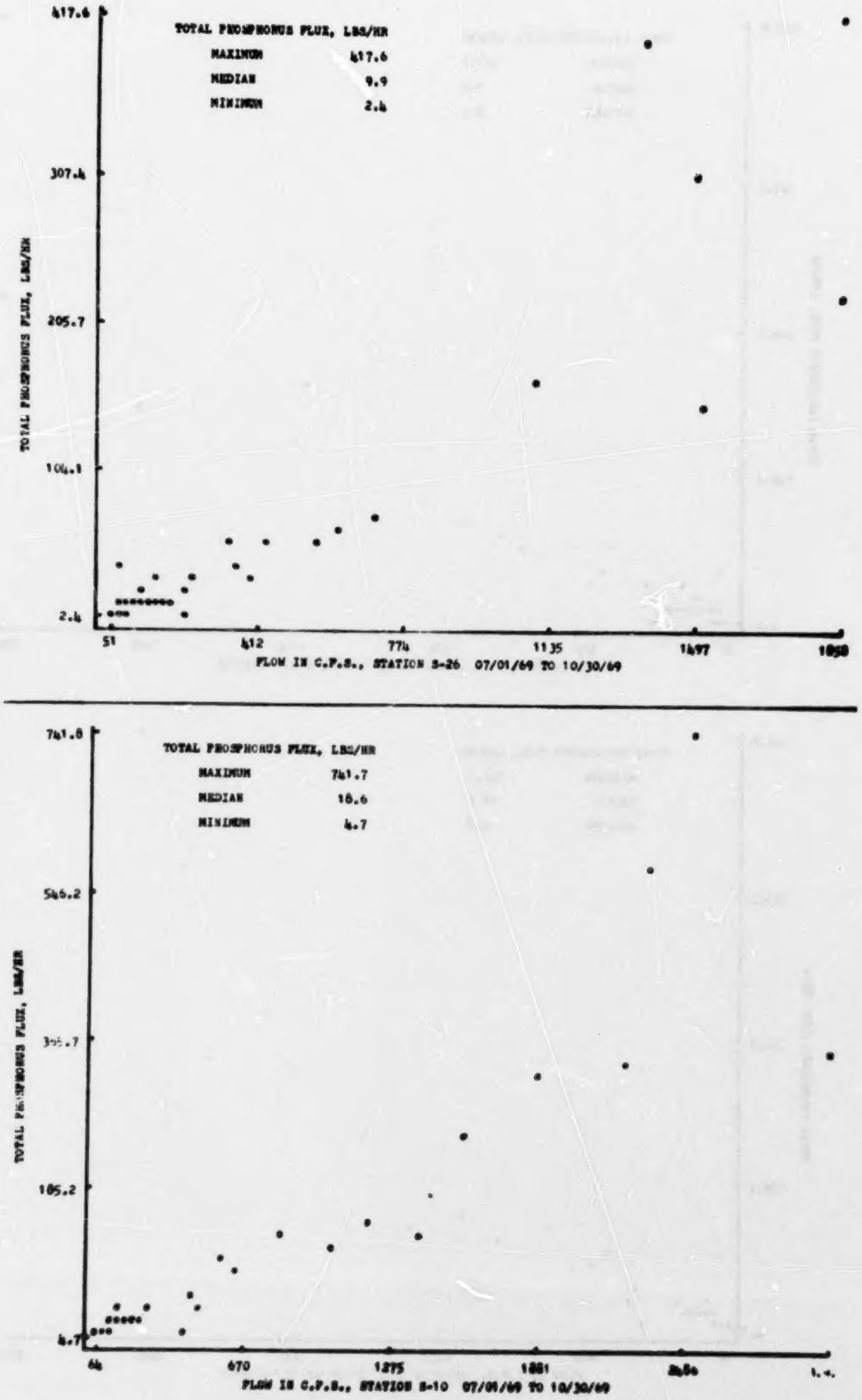
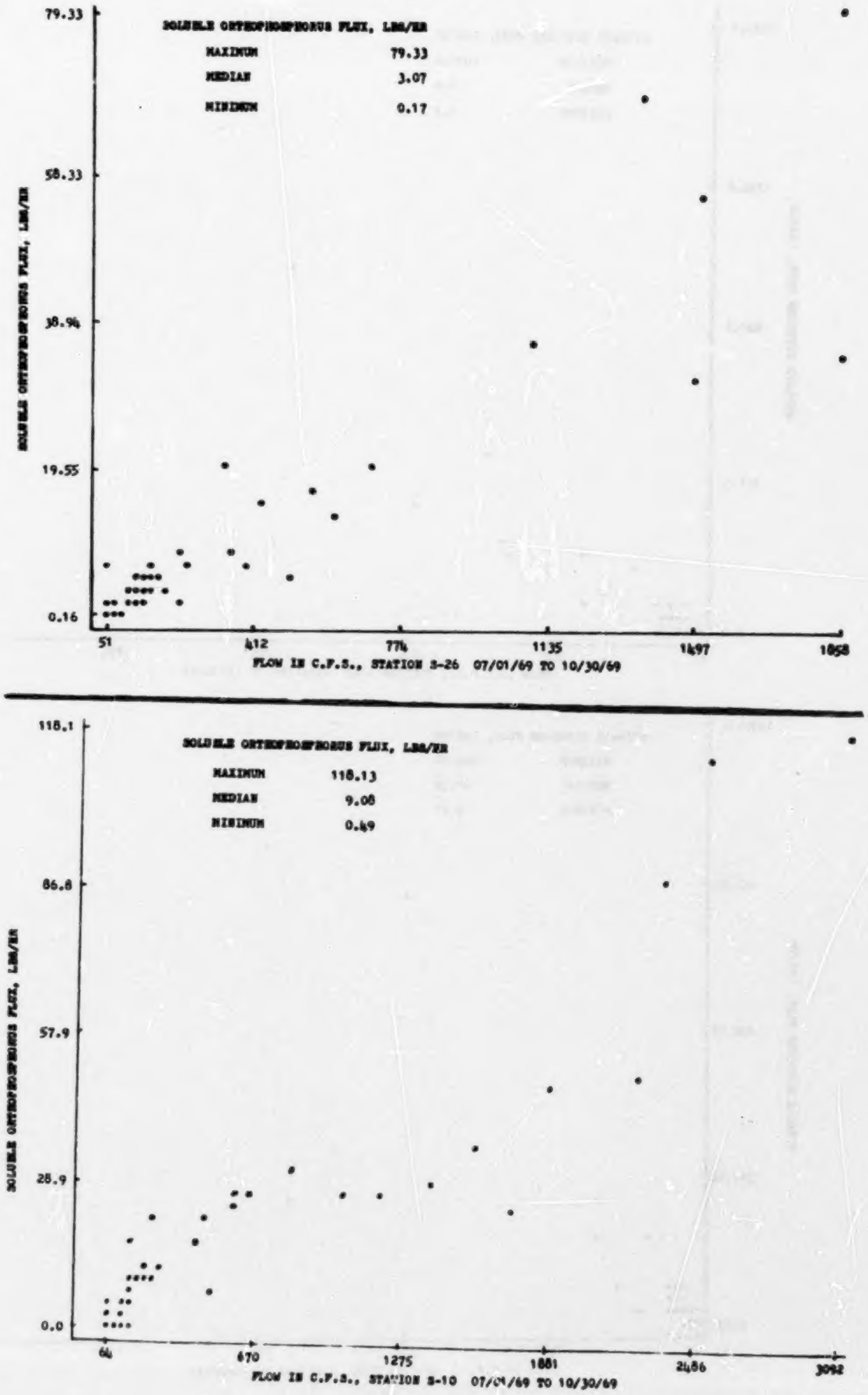


Figure 22. Relationship Between Soluble Orthophosphorus Flux and Flow Volume



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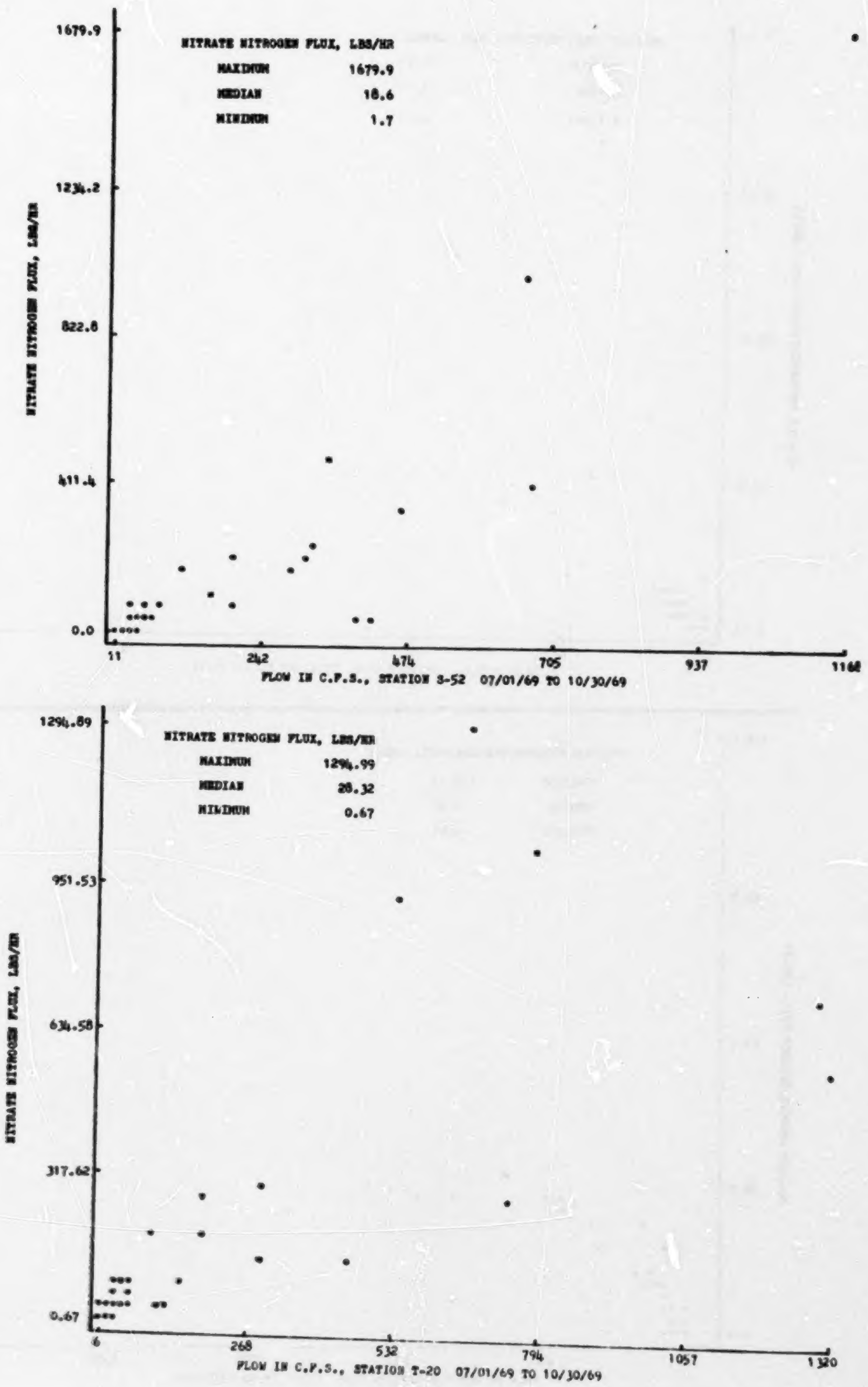
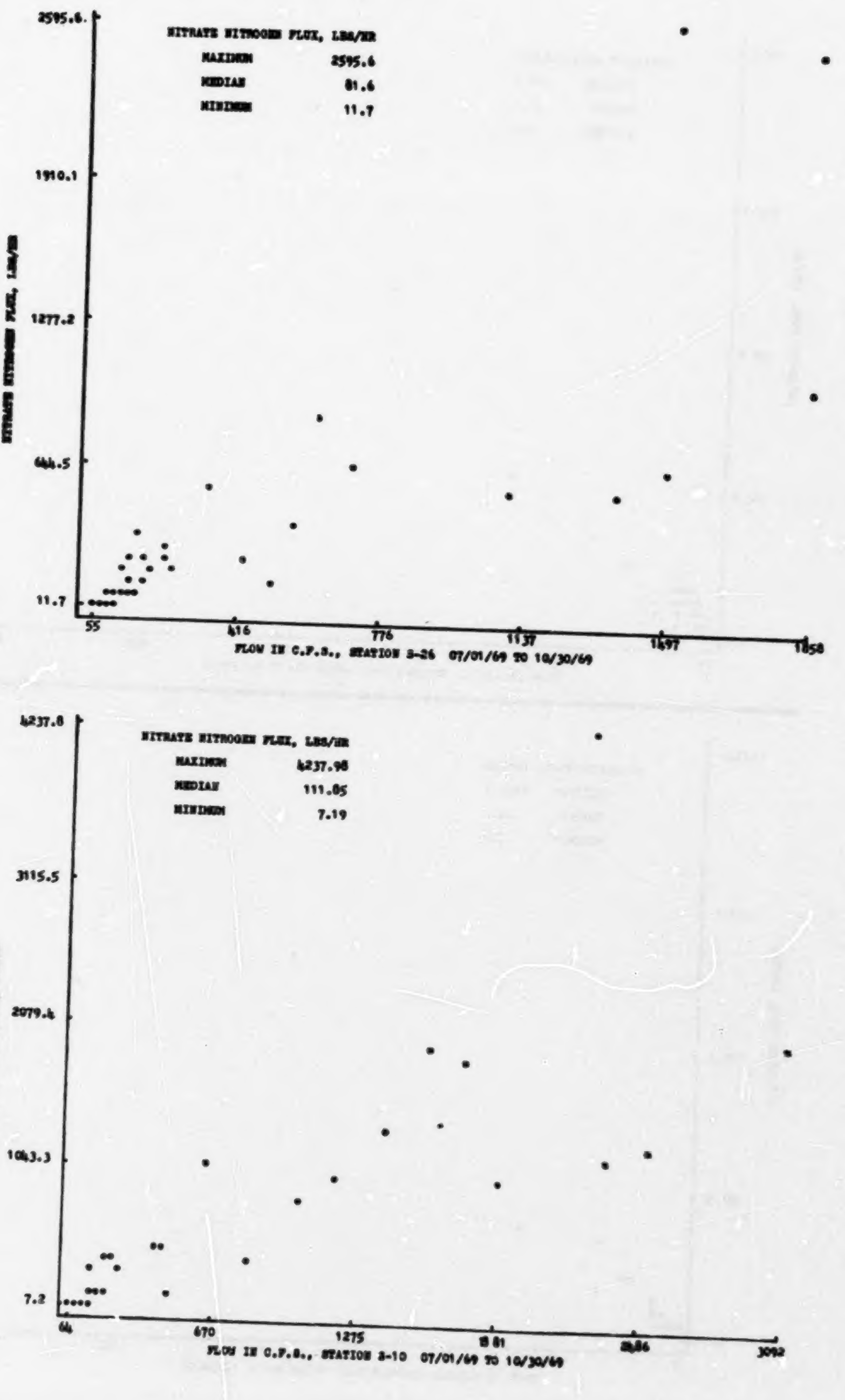


Figure 23. Relationship Between Nitrate-Nitrogen Flux and Flow Volume



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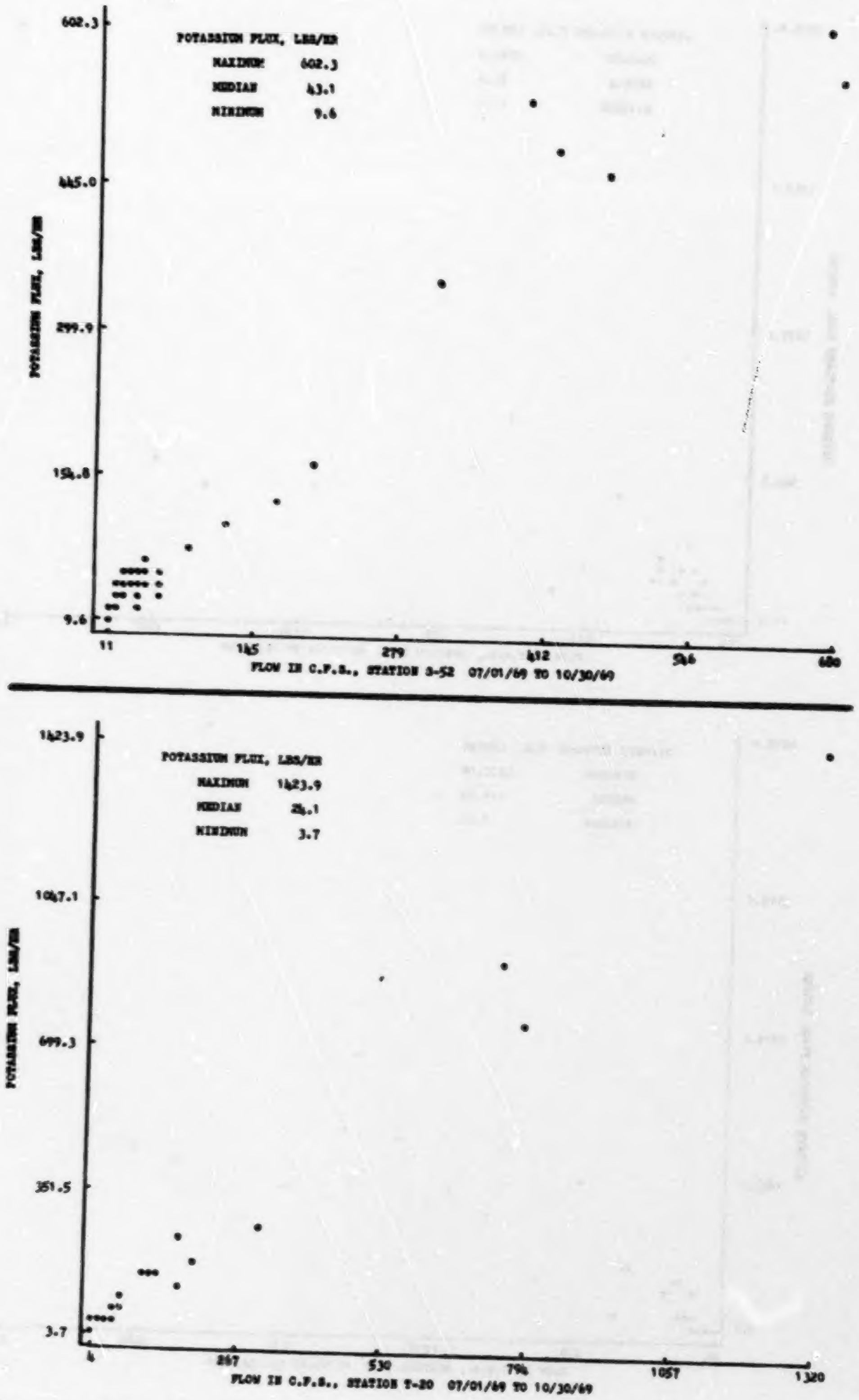

Figure 24. Relationship Between Potassium Flux and Flow Volume

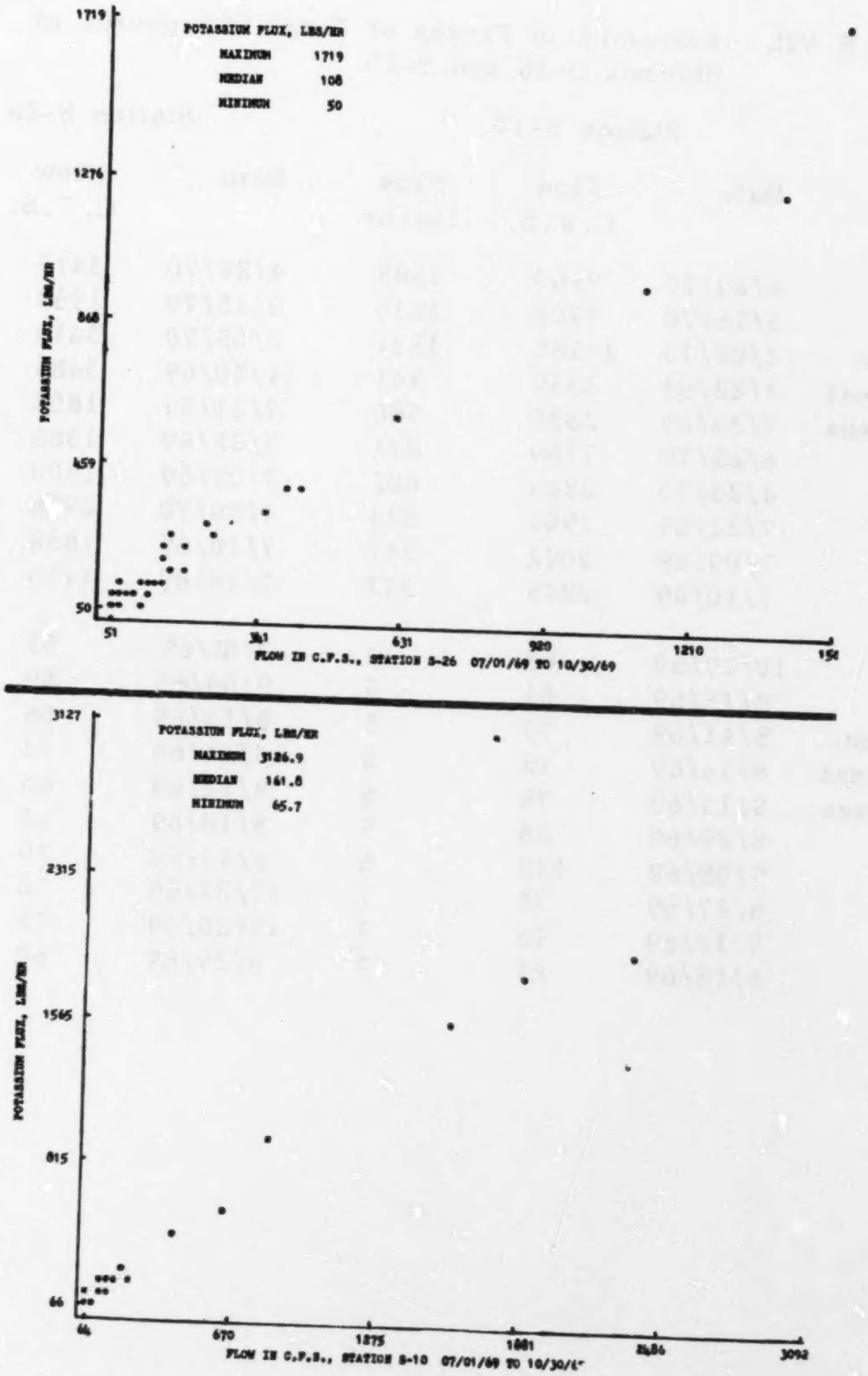

Figure 24 Continued

TABLE VII. Extremes in Fluxes of Total Phosphorus at Stations S-26 and S-10

	Station S-10			Station S-26		
	Date	Flow C.F.S.	Flux lbs/hr	Date	Flow C.F.S.	Flux lbs/hr
Ten Highest Fluxes	4/29/70	9160	1585	4/29/70	3415	583
	5/15/70	7704	1246	5/15/70	1962	211
	2/02/70	11185	1231	2/05/70	3618	227
	7/23/69	2539	741	11/20/69	3485	477
	7/24/69	2350	580	7/23/69	1858	417
	4/26/70	7760	871	7/22/69	1385	404
	4/23/70	2824	602	7/09/69	1500	306
	7/22/69	1902	324	4/20/70	2778	349
	7/09/69	3092	347	7/10/69	1858	221
	7/10/69	2245	343	7/24/69	1116	165
Ten Lowest Fluxes	10/29/69	68	4	9/01/69	51	2
	8/15/69	64	5	9/04/69	89	2
	8/11/69	75	5	8/15/69	66	2
	8/14/69	78	6	8/14/69	72	3
	8/13/69	78	6	8/12/69	64	3
	8/29/69	68	5	8/18/69	69	3
	9/08/69	128	6	8/11/69	70	3
	8/27/69	78	7	10/27/69	72	3
	8/12/69	78	7	10/20/69	75	2
	8/18/69	89	7	8/29/69	60	3

during the relatively few days of high flow and flood conditions completely dwarf the fluxes of the majority of the time having medium and low flows.

The problem of estimating nutrient fluxes into Lake Erie is complicated by the fact that there is considerable variation in nutrient fluxes at given flows. Accurate annual loading data would require frequent monitoring during high flow periods but one could probably disregard fluxes during medium and low flow periods.

Relative Contributions of Domestic and Agricultural Sources of Phosphorus

Within the study area, municipal waste and rural runoff constitute the two major sources of phosphorus. Industrial waste and urban runoff are probably insignificant. The relative importance of agricultural runoff in comparison with municipal waste as sources of phosphorus is very important to establish since all areas surrounding Lake Erie are under pressure to reduce phosphorus loading. Since our data may be pertinent with respect to determining loading sources, it will be briefly discussed.

The data presented above indicate when the bulk of the phosphorus is moving into Lake Erie (i.e., during high flows), but they do not indicate where the phosphorus is coming from. The high fluxes at high flows have already been noted by the F.W.Q.A. in the Lake Erie South Shore Tributary Loading Data Summary of 1967.[11]

Existing data can give widely divergent estimates of loading sources depending on interpretation and assumptions. To illustrate this, two examples will be discussed using our own data for the July through October period.

Although the fluxes varied tremendously, an average daily flux at station S-10 can be calculated as 75 pounds per hour. The average waste loading from the Tiffin sewage treatment plant for this period was reported to be about 13 pounds per hour. Assuming that this represents about 40% of the total upstream municipal loading, then the total upstream municipal loading would be 32 pounds per hour or 42% of the average hourly flux for the period.

The fact that during low flows the total fluxes at S-10 dropped to 4 to 5 pounds per hour attests to a loss of phosphorus to the stream bottom during low flow conditions. Since the median flux was only 18.6 pounds per hour, it is also apparent that losses of phosphorus to the stream bottom are not confined to low flow periods. In the absence of losses to the stream bottom the municipal wastes themselves would maintain a flux of 32 pounds per hour at station S-10. One can assume that the high fluxes during high flow include large amounts of the phosphorus that disappeared during low flows. This would mean that significant amounts of the fluxes during high flows come from accumulated municipal wastes washing out of the stream. Given this assumption, the estimated percentage of the phosphorus from municipal wastes remains at 42, and the rural runoff would be no more than 58% of the total flux.

A second way to estimate the sources would be to assume that the fluxes at low flows represent the municipal contributions to loading and that virtually zero rural runoff occurs during these low flow periods. Averaging the ten lowest fluxes at S-10 during this period gives a value of 6.29 pounds per hour which constitutes 8.3% of the average daily flux. Rural runoff could then account for over 90% of the total flux. This way of calculation assumes that the phosphorus from municipal sources which disappears from the water during low and medium flows does not reappear during high flow. Thus the fluxes at high flows would represent primarily rural runoff. Support for this interpretation comes from the data from station T-20 where the phosphate concentrations during high flow periods fall in the same range as at the stations along the Sandusky. Yet the basin upstream from T-20 is entirely rural.

The calculations of the previous two paragraphs are merely meant to illustrate diverse interpretations of the same data. Even if one of the above would prove to be a "correct" interpretation, the figures would be inaccurate since the data do not include the high flow and high flux conditions in the late winter and early spring. The inclusion of these data would tend to increase the percentage of phosphorus loading attributed to agricultural runoff.

For the Lake Erie Basin as a whole, it is estimated that 72% of the phosphorus entering the lake comes from domestic sources and

17% from agricultural runoff.[12] These percentages undoubtedly reflect the effects of domestic loading from the population centers located on the shores of the lake. In the Sandusky River Basin and probably in most of northwestern Ohio, agricultural runoff appears to be a much more important source of phosphorus than domestic inputs, even if all of the phosphorus entering streams from the sewage treatment plants reaches Lake Erie.

Accurate estimates of the importance of municipal wastes and rural runoff would be valuable as they relate to the benefits to be realized from pending requirements for tertiary treatment. To what extent is tertiary treatment for towns such as Tiffin and Upper Sandusky justified on the basis of reducing phosphorus loading into Lake Erie? Will increased phosphorus removal in sewage treatment plants improve water quality in streams where agricultural phosphorus loading is so important? Could consideration of river flow conditions and flow augmentation possibilities be coupled to some kind of intermittent phosphorus removal process in such a way as to provide more favorable economic benefits? These questions are raised here not only because they are important in themselves but because the addition of tertiary treatment will also interact with the benefits to be realized from flow augmentation.

Relationship Between Suspended Solids and Total Phosphorus

That phosphorus loading accompanies silt loading during agricultural surface runoff is well established.[8, 13, 14] Apparently the phosphorus is physically bound to exchange sites within the silt particles. Figure 25 shows the relationship between total suspended solids and concentrations of phosphorus at stations T-20 and S-10.

The data presented are taken from all that was available during the investigation, hence it includes lots of data from the July to October period and limited data from the following winter and spring. Total suspended solids were not measured as frequently as the phosphorus so the data are rather limited. A positive correlation between concentrations of total suspended solids and total phosphorus is nevertheless apparent. There is, however, considerable scatter.

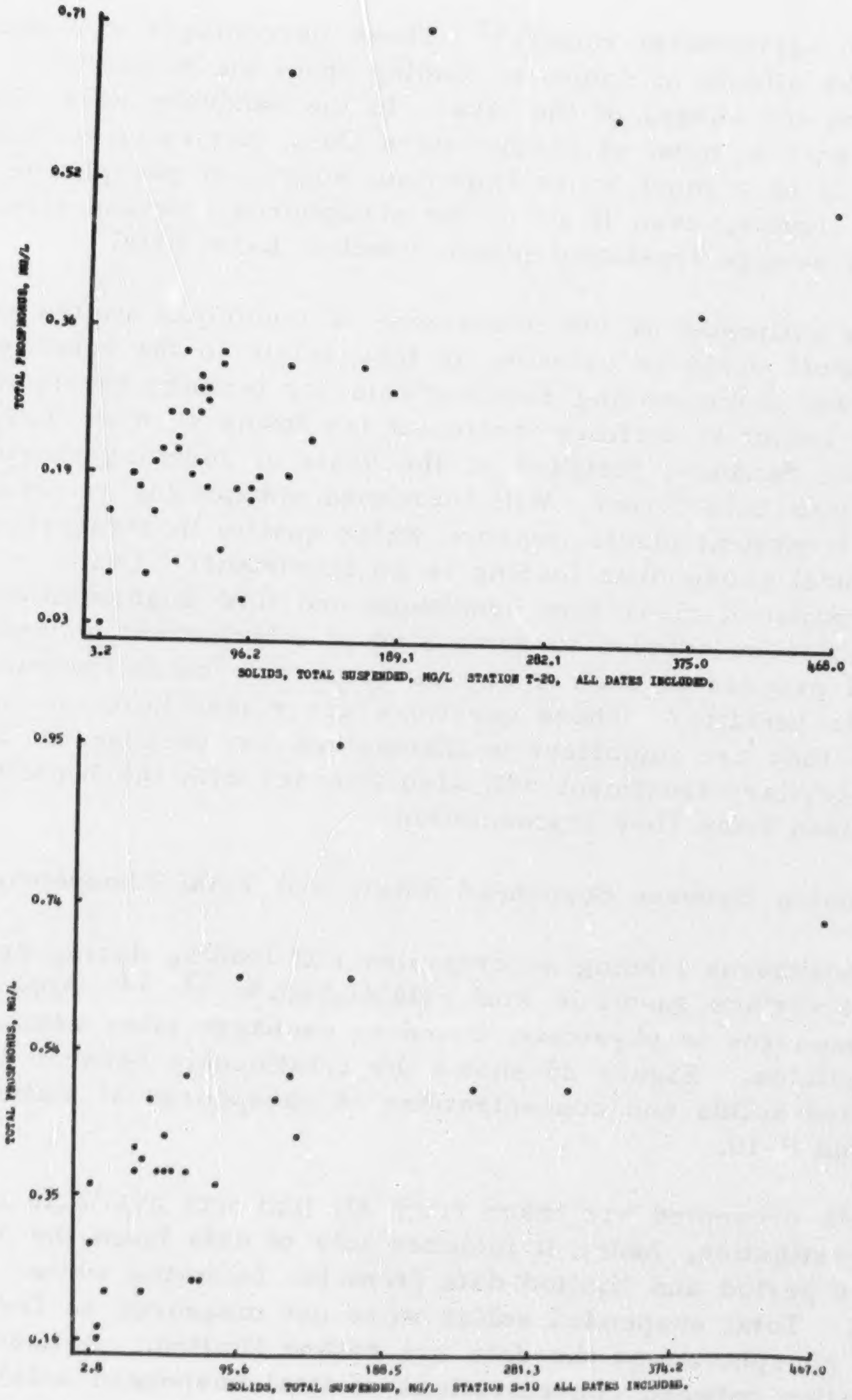

Figure 25. Relationship Between Total Phosphorus Concentration and Total Suspended Solids

Since trends in farming within the basin include increasing amounts of plowing during the fall and winter months it is possible that silt loading and phosphorus loading from rural runoff will increase within the basin.

Relationship Between Concentration and Conductivity

Since the U.S. Geological Survey bases its choice of samples for analysis on conductivity, the relationship between conductivity and concentration of the chemicals studied here is of some interest. Current practice by the U.S.G.S. in many basins in the state is to collect samples twice per week and then analyze the samples of maximum and minimum conductivity for a given month.

Figure 26 shows the relationship between the concentration of the background group of chemicals and conductivity. For all of these chemicals there is a strong positive correlation between conductivity and concentration. Thus analysis of the extremes of conductivity would tend to give extremes in the values for the background chemicals.

Such is not the case for the plant nutrients as can be seen in Figure 27. There is no apparent correlation between conductivity and concentration for the nutrients. This fact should be kept in mind when using the U.S.G.S. data. The U.S.G.S. data represent more-or-less random samples with respect to nutrient concentrations.

Concentrations of Fecal Coliform Bacteria

Table 8 shows the results of measurements of fecal coliform bacteria in the study area. These measurements are of interest not only because of their utility as indicators of recent sewage pollution but also in view of the designation of the river as an Ohio State Scenic River. The data indicate that the fecal coliform counts throughout the entire study section (which corresponds to the scenic river section) considerably exceed the recommended limits for safe recreational water. Their general presence throughout the entire section probably cannot be accounted for exclusively in terms of loading from towns. Analysis of rates of die-off coupled with time of travel information could confirm this but such information is currently not available. Probably the generally high

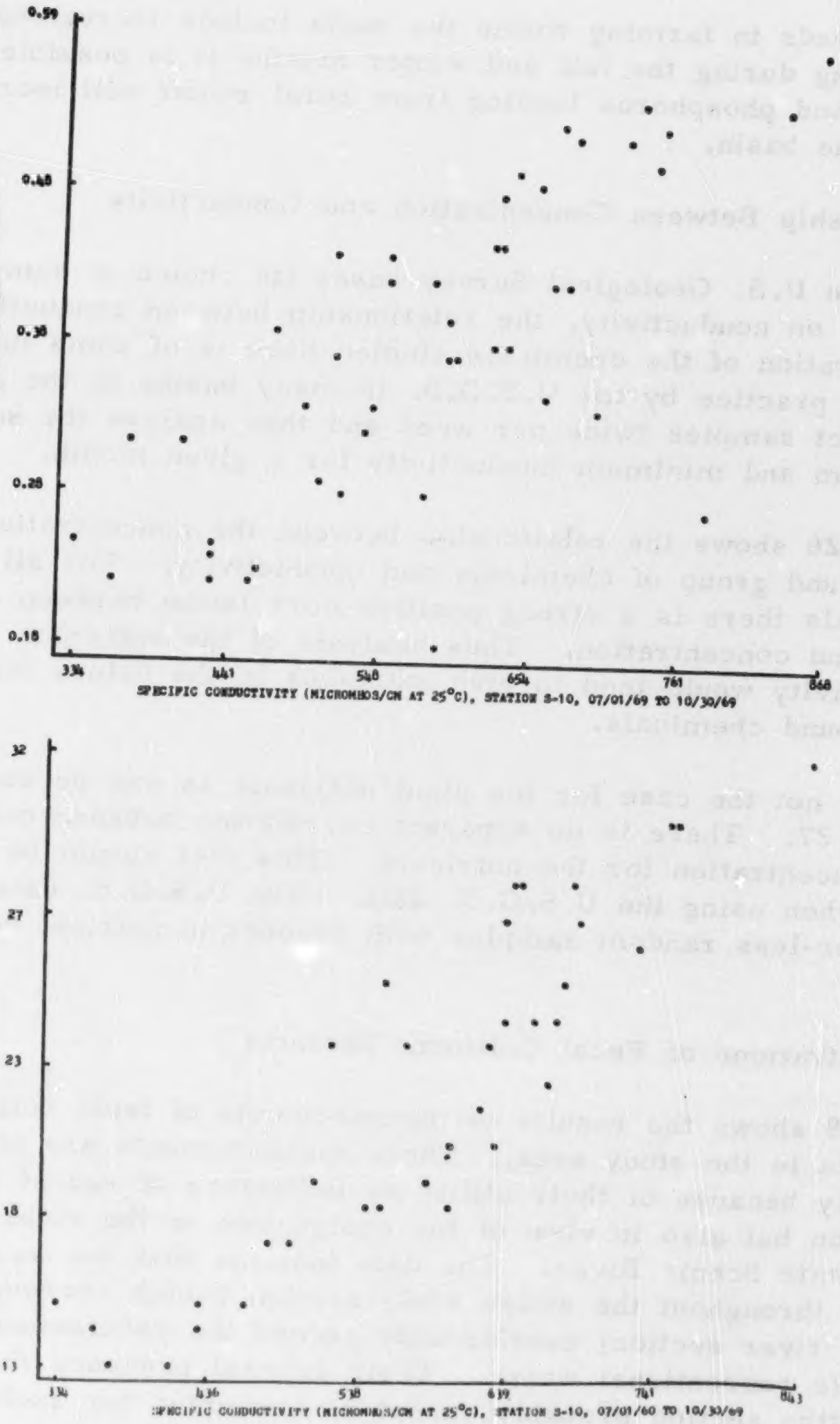

Figure 26. **Relationship Between Concentrations of Background Chemicals and Specific Conductivity**

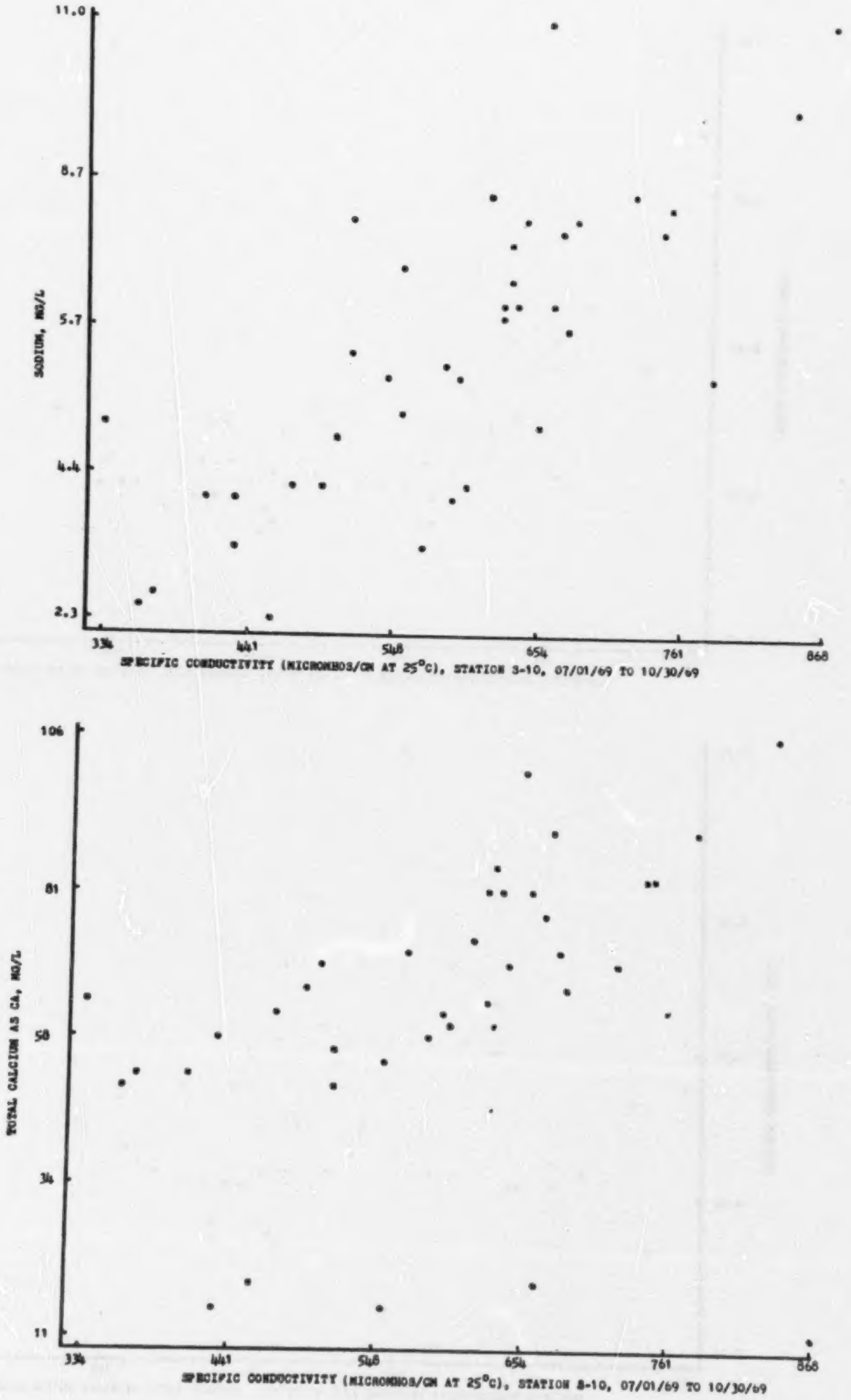

Figure 26 Continued

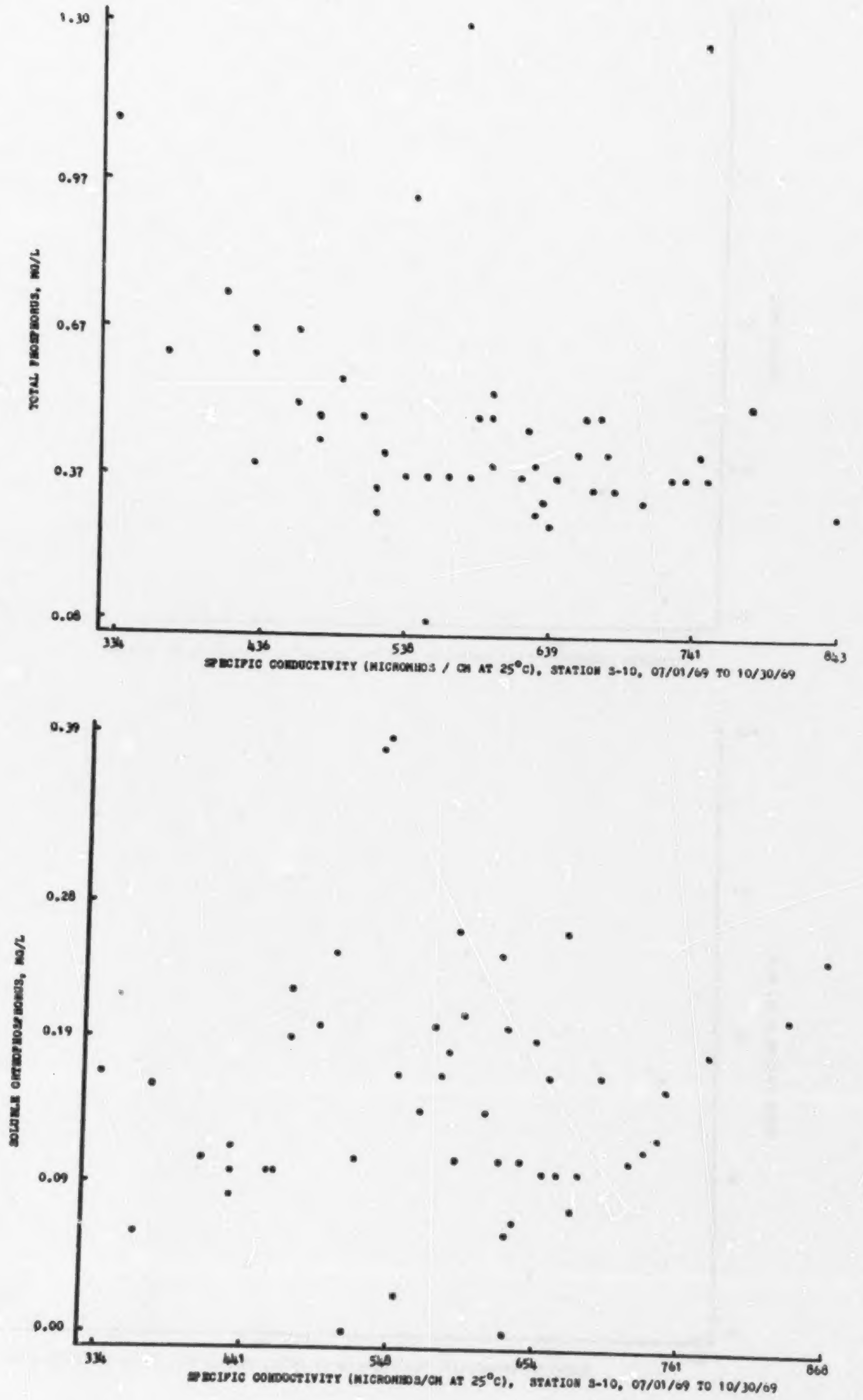

Figure 27. Relationship Between Concentrations of Plant Nutrients and Specific Conductivity

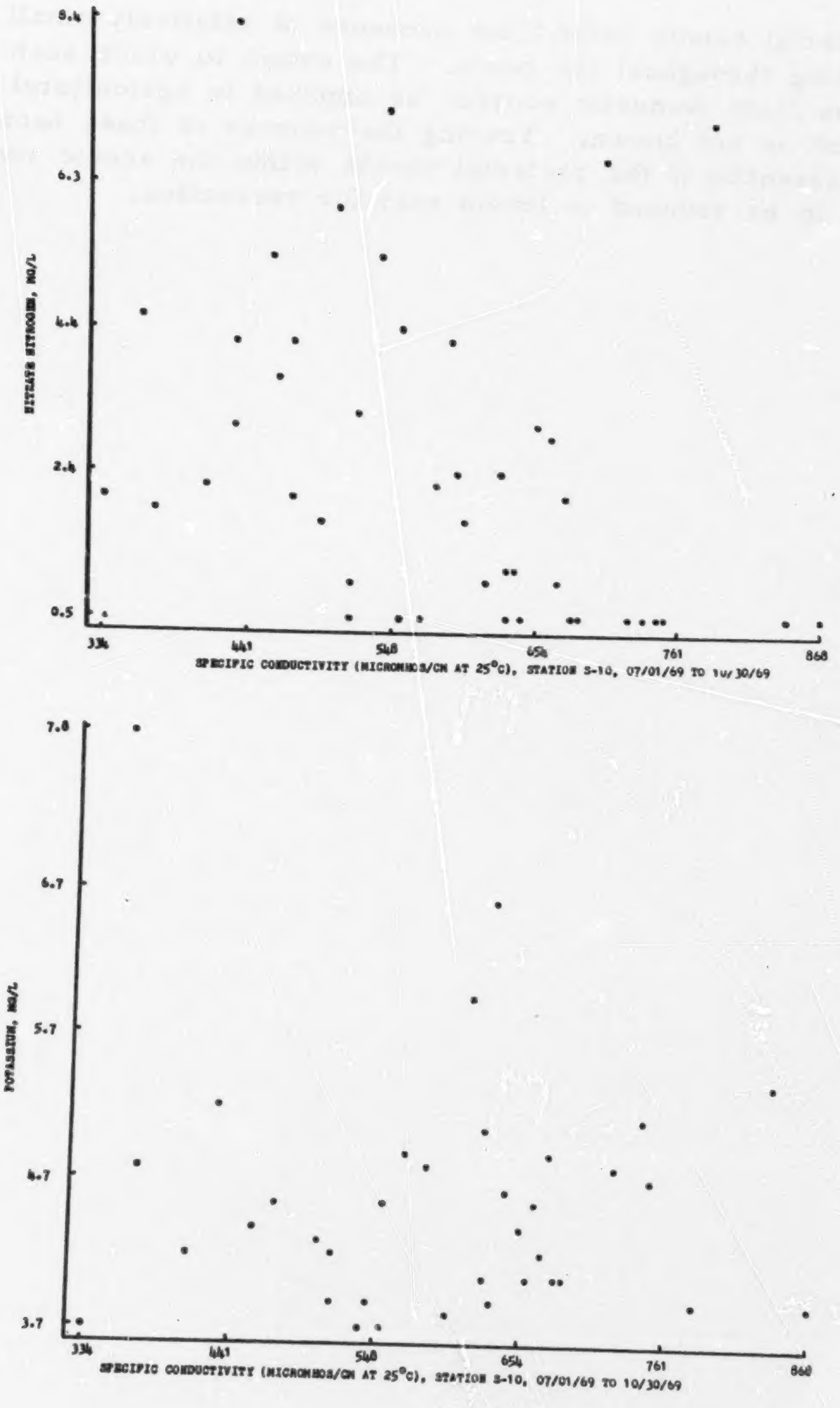

Figure 27 Continued

bacterial counts reflect the presence of relatively small sewage loading throughout the basin. The extent to which such loadings come from domestic sources as opposed to agricultural feedlot runoff is not known. Tracing the sources of these bacteria will be essential if the bacterial counts within the scenic river area are to be reduced to levels safe for recreation.

TABLE VIII. Sewage Pollution of Sandusky River as Indicated by Fecal Coliform Bacteria July and August, 1969

	Location		Number of Tests	Geometric Mean	Maximum Count	Minimum Count
1.	Tyndal Bridge	(S-10)	25	1,313	16,000	60
2.	Wolf Creek	(W-02)	9	509	2,500	70
3.	Seneca 38	(S-20)	29	1,907	10,220	320
4.	Huss St. Bridge	(S-22)	31	2,042	13,500	560
5.	Rock Creek	(R.C.)	10	3,390	20,000	1200
6.	Ella Street	(S-24)	28	1,697	14,400	230
7.	Honey Creek	(H-20)	32	1,106	6,000	330
8.	Scotts Bridge	(S-26)	25	675	13,000	60
9.	Wyandot 16	(S-38)	26	1,033	28,800	320
10.	Tymochtee	(T-20)	30	1,432	12,400	380
11.	State Rt. 103	(S-40)	19	1,460	38,000	200
12.	Wyandot 121	(S-52)	29	15,753	148,000	1870

SECTION XII

ADDITIONAL DATA AND ANALYSIS

In addition to the data presented and discussed in previous sections, data are available on pH and temperature for all samples collected. Analyses of alkalinities and chlorides were done on a less frequent basis but considerable data for these were accumulated. Approximately six chlorophyll tests were done at each of 11 collection sites during the July through October period but discrepancies between replicate samples were large in relation to the differences between stations and times, so meaningful analysis is not feasible.

Discussion of data has primarily been limited to the analyses done at gage stations. Comparable data was collected at six other stations, but until stage discharge curves are developed for these stations and/or time of travel information becomes available, detailed analysis does not seem to be warranted. The data collected at these stations during the July through October period have been included in the Appendix.

All of the data collected during this study has been stored on computer disks. At any station, correlations between any two variables could be carried out and the results plotted in graphical form. Any desired transformations of the variables can be carried out prior to plotting the graphs. For example, the logs of the flows could have been used. Each plot plus a listing of all the point pairs is produced in less than one minute so literally thousands of correlations could have been investigated. Only the data considered relevant to flow augmentation effects have received detailed analysis. The additional analyses reported in Section XI represent by-products of the study and should be viewed as such. They have been included because of their possible relevance to other water quality investigations.

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ACKNOWLEDGMENTS

This study was an outgrowth of consultations with the Ohio Department of Natural Resources. Thanks are especially due to Mr. A. F. Woldorf of the Division of Water who was instrumental in setting up the early planning and coordination for this project. Mr. J. J. Molloy, District Chief of the U.S. Geological Survey, has been extremely helpful throughout this project in supplying stage-discharge tables, interim water flow data and interim water quality data.

The Environmental Protection Agency is to be thanked, not only for supporting this project, but also for the technical support extended by Dr. M. W. Lammering and Mr. B. Smith of the National Field Investigations Center in Cincinnati and Messrs. G. Harlow, E. Kramer and C. Kleveno of the Lake Erie Program Office. The loan of a fluorometer system for dye tracer studies from the National Field Investigation Center and a current meter from the Lake Erie Program Office is greatly appreciated. The help of the Project Officer, Dr. W. R. Duffer of the National Water Quality Control Research Program, Water Quality Office, Environmental Protection Agency, Robert S. Kerr Water Research Center, is also greatly appreciated.

The participation of several of our colleagues in the science departments at Heidelberg College contributed greatly to this project. These include Dr. J. J. Jackobs of the Computer Center, Mr. R. A. Wise of the Physics Department, Dr. D. Allenson of the Chemistry Department (now with the Division of Water Pollution Control, Department of Public Utilities, Cleveland, Ohio), and Mr. E. T. Ashworth of the Geology Department. Student technicians who participated in the study included B. Remick, J. Lather, and R. Stanforth.

The work of Mrs. D. B. Baker and Mrs. G. D. Knutson in preparing the figures and tables and in typing the final manuscript has been greatly appreciated by the authors.

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SECTION XIV

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SECTION XV

GLOSSARY

Time of Travel - The length of time it takes for water to move through a given section of a stream; also referred to as "time of passage."

Flow Velocity - The linear velocity of water at a given point in a stream; as flow velocity increases, time of travel decreases.

Flow Volume, River Flow, Stream Flow - The volume of water moving through a total cross section of a river per unit of time; expressed here as cubic feet of water per second (C.F.S.).

Flux - The amount of material moving through a cross section of the stream per unit time; obtained by multiplying the flow volume at a given site by the concentration of the material; expressed as pounds per hour or pounds per day.

Loading - Similar to flux but with the connotation of input into the river or input from the river into a downstream site.

Upground Reservoir - As used here, this term refers to reservoirs that are built adjacent to streams rather than by damming the streams. Water is usually pumped into the reservoirs. Construction generally involves excavating a large area which is then surrounded by dykes formed with the excavated materials.

Low Flows - As used here, this term refers to the lowest flows which occurred during the study period (see Table III). The lowest flows which occurred were greater than the levels to be maintained by flow augmentation.

Severe Low Flows - As used here, this term refers to flows falling below those which are equalled or exceeded 80% of the time. Flow augmentation would be used during periods of severe low flows.

Background Chemicals - As used here, refers to chemicals such as calcium, magnesium, and sodium, which are natural components of the ground water or surface runoff water. As a group they, along with fluoride, show increasing concentration with decreasing flow volume.

Plant Nutrients - As used here, refers to total phosphorus, soluble orthophosphorus, nitrate-nitrogen and potassium. These generally do not show increasing concentrations with decreasing flow. These chemicals also happen to be the plant nutrients (in the physiological sense) which are major constituents of fertilizer.

SECTION XVI

APPENDICES

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NOTES ON APPENDICES

1) Where concentrations of chemicals are shown, the concentrations are expressed in milligrams per liter.

2) Zeros appearing in the tables mean that no measurements were taken rather than zero concentration of the chemicals.

3) In Appendix L where stages are reported, the units are in feet and hundredths of feet. At stations S-10, S-26, S-52, H-20 and T-20 wire weight gages were used and increasing numbers represent increasing river stages. At the other locations the measurements represent the distances between the water surface and a fixed reference point on a bridge. For these stations increasing numbers represent decreasing river stages.

4) The appendix includes data for ten of the sampling locations. Except for total phosphorus, only the data obtained during the anticipated low flow periods of July through October are included. For total phosphorus, data obtained in the winter and spring are included. Only the chemicals which have been discussed within this report are listed. Complete records for these chemicals as well as records of pH and temperature and partial records of alkalinity, chlorides and suspended solids are available upon request.

Appendix A. Conductivity Micromhos/CM at 25° C

VARIABLE . . . CONDUCTIVITY

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
07/07/69	CONC	362.00	289.00	336.00	730.00	770.00	753.00	585.00	721.00	671.00	657.00
07/08/69	CONC	432.00	601.00	637.00	751.00	742.00	346.00	348.00	326.00	353.00	703.00
07/09/69	CONC	669.00	437.00	441.00	394.00	455.00	480.00	496.00	286.00	436.00	748.00
07/10/69	CONC	434.00	464.00	455.00	409.00	445.00	533.00	523.00	407.00	451.00	750.00
07/11/69	CONC	462.00	442.00	422.00	458.00	450.00	579.00	575.00	505.00	473.00	728.00
07/14/69	CONC	463.00	518.00	510.00	606.00	568.00	505.00	469.00	556.00	417.00	757.00
07/15/69	CONC	524.00	589.00	593.00	565.00	491.00	494.00	498.00	437.00	470.00	678.00
07/16/69	CONC	785.00	595.00	568.00	554.00	544.00	559.00	573.00	497.00	524.00	705.00
07/17/69	CONC	556.00	545.00	537.00	506.00	587.00	623.00	608.00	528.00	552.00	660.00
07/18/69	CONC	593.00	561.00	605.00	526.00	642.00	659.00	659.00	582.00	533.00	693.00
07/21/69	CONC	435.00	412.00	420.00	536.00	618.00	660.00	549.00	0.00	337.00	672.00
07/22/69	CONC	412.00	430.00	547.00	383.00	323.00	480.00	496.00	230.00	375.00	704.00
07/23/69	CONC	582.00	348.00	370.00	329.00	334.00	453.00	450.00	319.00	406.00	688.00
07/24/69	CONC	334.00	341.00	344.00	358.00	446.00	490.00	515.00	454.00	438.00	693.00
07/25/69	CONC	374.00	386.00	387.00	406.00	530.00	538.00	551.00	510.00	465.00	705.00
07/28/69	CONC	478.00	563.00	507.00	571.00	674.00	688.00	676.00	639.00	549.00	772.00
07/29/69	CONC	496.00	541.00	544.00	591.00	587.00	688.00	667.00	643.00	549.00	737.00
07/30/69	CONC	601.00	653.00	698.00	676.00	676.00	785.00	735.00	810.00	628.00	836.00
07/31/69	CONC	600.00	633.00	624.00	683.00	741.00	690.00	737.00	713.00	601.00	795.00
08/01/69	CONC	629.00	661.00	647.00	709.00	748.00	721.00	751.00	783.00	614.00	0.00
08/04/69	CONC	673.00	614.00	613.00	671.00	711.00	746.00	779.00	734.00	603.00	717.00
08/05/69	CONC	634.00	591.00	612.00	598.00	745.00	725.00	741.00	474.00	591.00	748.00
08/06/69	CONC	520.00	596.00	594.00	627.00	620.00	767.00	763.00	486.00	602.00	659.00
08/07/69	CONC	518.00	609.00	597.00	625.00	697.00	792.00	784.00	496.00	618.00	666.00
08/08/69	CONC	556.00	590.00	572.00	658.00	740.00	820.00	800.00	510.00	614.00	668.00

Appendix A Continued

VARIABLE . . . CONDUCTIVITY

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
08/11/69	CONC	638.00	642.00	632.00	747.00	884.00	925.00	891.00	636.00	664.00	871.00
08/12/69	CONC	683.00	665.00	649.00	689.00	868.00	907.00	821.00	576.00	607.00	704.00
08/13/69	CONC	690.00	692.00	680.00	0.00	884.00	920.00	807.00	617.00	631.00	719.00
08/14/69	CONC	729.00	717.00	0.00	490.00	883.00	896.00	852.00	662.00	630.00	736.00
08/15/69	CONC	647.00	712.00	687.00	657.00	837.00	880.00	832.00	698.00	606.00	697.00
08/18/69	CONC	755.00	698.00	687.00	771.00	905.00	970.00	751.00	763.00	639.00	714.00
08/19/69	CONC	749.00	715.00	694.00	824.00	933.00	962.00	812.00	780.00	632.00	776.00
08/20/69	CONC	738.00	729.00	709.00	845.00	835.00	795.00	456.00	809.00	647.00	778.00
08/21/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/22/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/25/69	CONC	661.00	567.00	540.00	583.00	638.00	6.80	647.00	594.00	621.00	694.00
08/26/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/27/69	CONC	631.00	583.00	548.00	571.00	679.00	654.00	699.00	609.00	645.00	676.00
08/28/69	CONC	599.00	605.00	561.00	595.00	767.00	716.00	741.00	622.00	657.00	692.00
08/29/69	CONC	587.00	554.00	531.00	584.00	800.00	745.00	779.00	625.00	620.00	670.00
09/01/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/04/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/08/69	CONC	0.00	0.00	0.00	636.00	693.00	891.00	750.00	470.00	429.00	721.00
09/09/69	CONC	680.00	749.00	732.00	550.00	661.00	794.00	785.00	518.00	483.00	769.00
09/11/69	CONC	0.00	580.00	0.00	636.00	604.00	816.00	803.00	491.00	520.00	774.00
09/12/69	CONC	0.00	557.00	564.00	676.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69	CONC	571.00	629.00	617.00	614.00	742.00	849.00	824.00	537.00	579.00	655.00
09/16/69	CONC	636.00	712.00	659.00	677.00	866.00	959.00	902.00	0.00	615.00	700.00
09/17/69	CONC	620.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/18/69	CONC	0.00	573.00	479.00	651.00	784.00	938.00	479.00	513.00	449.00	597.00

Appendix A Continued

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VARIABLE . . . CONDUCTIVITY
 DATE          S-10       S-20       S-22       S-26       S-38       S-40       S-52       T-20       H-20       W-02

09/19/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/22/69
    CONC     478.00       0.00       0.00     433.00     571.00       0.00     692.00       0.00     553.00     714.00
09/23/69
    CONC       0.00     435.00     429.00       0.00     571.00     679.00     692.00     499.00       0.00       0.00
09/24/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/25/69
    CONC       0.00     534.00     522.00     572.00     694.00     795.00     801.00     616.00     609.00     745.00
09/26/69
    CONC       0.00       0.00       0.00     604.00     703.00     807.00     746.00     627.00     527.00       0.00
09/29/69
    CONC     706.00     660.00     719.00     799.00     728.00     972.00     938.00     789.00     717.00       0.00
09/30/69
    CONC     657.00     830.00     753.00     747.00     853.00    1280.00     868.00     727.00     617.00     784.00
10/01/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/02/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/07/69
    CONC     640.00     671.00     650.00     680.00     827.00     868.00     777.00     691.00     607.00     762.00
10/09/69
    CONC       0.00       0.00       0.00     741.00     834.00     873.00     860.00     748.00     627.00       0.00
10/14/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/16/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/20/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/21/69
    CONC     843.00     888.00     852.00       0.00    1070.00    1051.00     875.00     905.00     709.00     861.00
10/23/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/27/69
    CONC       0.00       0.00       0.00       0.00    1009.00       0.00       0.00     939.00     732.00       0.00
10/28/69
    CONC     868.00     874.00     852.00       0.00     953.00     991.00     934.00     907.00     668.00     839.00
10/29/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
11/03/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
11/04/69
    CONC       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
11/10/69
    CONC    1000.00     902.00     939.00       0.00       0.00       0.00       0.00       0.00       0.00     951.00
11/11/69
    CONC       0.00     894.00       0.00       0.00     836.00     865.00    8520.00     771.00     703.00     929.00
11/12/69
    CONC       0.00       0.00     853.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
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Appendix B. Fluoride Concentration Mg/L

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VARIABLE . . .    FLUORIDE
 DATE        S-10      S-20      S-22      S-26      S-38      S-40      S-52      T-20      H-20      W-02

07/07/69
    CONC     0.22      0.22      0.22      0.39      0.42      0.43      0.35      0.36      0.34      0.00
07/08/69
    CONC     0.24      0.31      0.34      0.40      0.41      0.25      0.24      0.17      0.19      0.30
07/09/69
    CONC     0.35      0.28      0.28      0.24      0.24      0.29      0.27      0.19      0.21      0.34
07/10/69
    CONC     0.25      0.25      0.24      0.22      0.22      0.26      0.29      0.19      0.20      0.34
07/11/69
    CONC     0.22      0.20      0.20      0.21      0.24      0.27      0.27      0.19      0.19      0.29
07/14/69
    CONC     0.23      0.27      0.22      0.26      0.25      0.24      0.24      0.20      0.18      0.31
07/15/69
    CONC     0.28      0.32      0.33      0.33      0.29      0.33      0.36      0.22      0.26      0.42
07/16/69
    CONC     0.27      0.26      0.25      0.24      0.25      0.27      0.29      0.08      0.21      0.33
07/17/69
    CONC     0.44      0.42      0.42      0.41      0.47      0.50      0.51      0.36      0.40      0.52
07/18/69
    CONC     0.18      0.22      0.20      0.20      0.24      0.25      0.24      0.20      0.21      0.27
07/21/69
    CONC     0.22      0.20      0.20      0.24      0.24      0.29      0.22      0.00      0.20      0.32
07/22/69
    CONC     0.31      0.37      0.40      0.35      0.32      0.37      0.35      0.27      0.29      0.45
07/23/69
    CONC     0.28      0.28      0.25      0.24      0.24      0.32      0.33      0.26      0.23      0.44
07/24/69
    CONC     0.25      0.24      0.26      0.27      0.30      0.35      0.42      0.27      0.24      0.46
07/25/69
    CONC     0.31      0.30      0.32      0.32      0.40      0.47      0.50      0.32      0.29      0.56
07/28/69
    CONC     0.39      0.38      0.35      0.38      0.43      0.43      0.43      0.35      0.32      0.50
07/29/69
    CONC     0.34      0.38      0.35      0.39      0.41      0.43      0.44      0.34      0.31      0.47
07/30/69
    CONC     0.37      0.44      0.40      0.44      0.49      0.52      0.53      0.30      0.35      0.54
07/31/69
    CONC     0.37      0.45      0.36      0.42      0.45      0.54      0.55      0.42      0.32      0.70
08/01/69
    CONC     0.38      0.45      0.36      0.40      0.48      0.39      0.48      0.30      0.33      0.50
08/04/69
    CONC     0.42      0.38      0.36      0.38      0.39      0.44      0.47      0.35      0.33      0.43
08/05/69
    CONC     0.48      0.46      0.44      0.46      0.59      0.55      0.65      0.33      0.30      0.60
08/06/69
    CONC     0.44      0.45      0.41      0.44      0.45      0.56      0.60      0.32      0.38      0.53
08/07/69
    CONC     0.37      0.52      0.38      0.45      0.49      0.58      0.63      0.33      0.40      0.52
08/08/69
    CONC     0.42      0.47      0.42      0.44      0.48      0.64      0.74      0.34      0.41      0.52
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Appendix B Continued

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VARIABLE . . .     FLUORIDE
 DATE            S-10      S-20      S-22      S-26      S-30      S-40      S-52      T-20      N-30      N-62

08/11/69
     CONC        0.45      0.46      0.42      0.44      0.56      0.60      0.62      0.33      0.41      0.51
08/12/69
     CONC        0.42      0.46      0.36      0.39      0.55      0.62      0.63      0.33      0.38      0.48
08/13/69
     CONC        0.52      0.52      0.46      0.00      0.68      0.66      0.70      0.37      0.41      0.53
08/14/69
     CONC        0.52      0.61      0.00      0.45      0.65      0.65      0.68      0.37      0.42      0.54
08/15/69
     CONC        0.50      0.63      0.46      0.44      0.64      0.64      0.70      0.40      0.41      0.52
08/18/69
     CONC        0.53      0.48      0.43      0.49      0.64      0.67      0.56      0.39      0.42      0.53
08/19/69
     CONC        0.51      0.42      0.36      0.43      0.53      0.55      0.53      0.34      0.33      0.46
08/20/69
     CONC        0.55      0.55      0.44      0.54      0.56      0.58      0.35      0.42      0.40      0.56
08/21/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
08/22/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
08/25/69
     CONC        0.49      0.52      0.48      0.52      0.56      0.56      0.60      0.42      0.46      0.51
08/26/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
08/27/69
     CONC        0.45      0.62      0.50      0.54      0.56      0.58      0.64      0.40      0.43      0.51
08/28/69
     CONC        0.40      0.57      0.58      0.54      0.63      0.58      0.62      0.41      0.41      0.50
08/29/69
     CONC        0.42      0.54      0.47      0.53      0.62      0.60      0.73      0.40      0.42      0.52
09/01/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/04/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/08/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/09/69
     CONC        0.53      0.52      0.48      0.37      0.46      0.53      0.56      0.29      0.27      0.66
09/11/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/12/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/15/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/16/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/17/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/18/69
     CONC        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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Appendix B Continued

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VARIABLE . . .     FLUORIDE
 DATE          S-10        S-20        S-22        S-26        S-38        S-40        S-52        T-20        M-20        W-02

09/19/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
09/22/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
09/23/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
09/24/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
09/25/69
     CONC      0.00        0.36        0.33        0.36        0.45        0.56        0.61        0.33        0.28        0.46
09/26/69
     CONC      0.00        0.00        0.00        0.40        0.47        0.54        0.57        0.33        0.33        0.00
09/29/69
     CONC      0.34        0.39        0.34        0.37        0.44        0.45        0.48        0.34        0.25        0.00
09/30/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/01/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/02/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/07/69
     CONC      0.38        0.44        0.35        0.40        0.53        0.56        0.54        0.32        0.31        0.44
10/09/69
     CONC      0.00        0.00        0.00        0.44        0.54        0.55        0.56        0.00        0.33        0.00
10/14/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/16/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/20/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/21/69
     CONC      0.55        0.62        0.40        0.00        0.59        0.64        0.60        0.41        0.38        0.54
10/23/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
10/27/69
     CONC      0.00        0.00        0.00        0.00        0.56        0.00        0.00        0.45        0.36        0.00
10/28/69
     CONC      0.59        0.61        0.50        0.00        0.56        0.64        0.70        0.46        0.37        0.56
10/29/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
11/03/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
11/04/69
     CONC      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
11/10/69
     CONC      0.00        0.00        2.90        0.00        0.00        0.00        0.00        0.00        0.00        0.00
11/11/69
     CONC      0.00        0.40        0.00        0.00        0.41        0.48        0.52        0.27        0.23        0.35
11/12/69
     CONC      0.00        0.00        0.34        0.00        0.00        0.00        0.00        0.00        0.00        0.00
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Appendix C. Sodium Concentration Mg/L

VARIABLE . . . SODIUM

DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
07/07/69 CONC	2.50	2.50	2.60	8.60	7.80	9.20	7.40	8.70	6.00	6.00
07/08/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/09/69 CONC	7.00	3.60	3.30	2.70	3.20	3.80	3.70	1.00	3.60	6.20
07/10/69 CONC	3.40	3.80	3.50	2.80	2.90	4.00	4.30	2.20	3.50	7.30
07/11/69 CONC	2.30	2.80	3.60	2.80	3.00	4.10	4.10	2.40	2.40	7.00
07/14/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/15/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/16/69 CONC	5.80	5.20	4.60	4.40	4.00	4.40	5.10	3.30	4.00	10.00
07/17/69 CONC	5.40	4.00	4.00	3.60	4.40	3.80	5.20	3.10	3.80	9.60
07/18/69 CONC	4.00	0.00	0.00	0.00	6.20	0.00	0.00	0.00	0.00	0.00
07/21/69 CONC	4.00	3.50	3.30	4.30	0.00	7.60	6.20	0.00	2.30	10.00
07/22/69 CONC	4.00	3.50	4.20	3.00	2.10	4.00	4.20	1.50	2.40	12.00
07/23/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/24/69 CONC	5.10	2.60	2.50	2.50	2.20	5.10	5.20	1.90	3.00	10.00
07/25/69 CONC	2.70	3.20	3.10	2.60	4.20	4.80	5.00	3.20	3.20	12.00
07/28/69 CONC	4.20	4.70	3.80	4.20	5.10	6.10	4.80	4.20	4.00	11.00
07/29/69 CONC	4.30	4.80	4.30	4.60	5.90	6.60	7.50	4.50	4.50	13.00
07/30/69 CONC	4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/31/69 CONC	0.00	4.40	4.30	4.50	5.00	6.40	8.80	4.80	4.30	18.00
08/01/69 CONC	7.00	5.40	4.80	6.10	6.30	8.50	10.00	6.50	4.80	14.00
08/04/69 CONC	8.00	6.50	5.70	6.00	7.30	10.00	15.00	3.90	4.90	0.00
08/05/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/06/69 CONC	6.20	6.20	5.30	5.50	5.80	8.50	11.00	3.80	4.80	11.00
08/07/69 CONC	8.10	7.80	6.20	6.90	7.20	9.50	1.20	4.20	5.60	12.00
08/08/69 CONC	7.50	7.40	6.20	7.40	8.50	12.00	14.00	4.40	5.80	14.00

Appendix C Continued

VARIABLE . . . SODIUM DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	[illegible]	W-02
08/11/69										
CONC	7.80	7.20	6.10	6.50	8.50	11.00	11.00	4.60	4.60	11.00
08/12/69										
CONC	8.10	8.20	6.10	6.60	10.00	9.00	9.00	4.30	4.40	9.00
08/13/69										
CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/14/69										
CONC	8.50	8.60	0.00	6.30	9.50	11.00	11.00	3.00	4.30	11.00
08/15/69										
CONC	8.20	8.20	4.20	4.20	9.40	11.00	13.00	3.40	4.20	12.00
08/18/69										
CONC	8.30	7.20	6.20	7.10	10.00	12.00	8.80	6.20	4.30	10.00
08/19/69										
CONC	8.00	8.20	6.50	8.30	8.00	8.00	8.00	6.70	4.50	8.00
08/20/69										
CONC	0.00	8.50	6.50	0.00	10.00	10.00	5.50	7.00	5.00	10.00
08/21/69										
CONC	8.80	7.90	8.50	10.00	6.10	5.20	4.20	8.90	5.40	10.00
08/22/69										
CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/25/69										
CONC	11.00	6.50	7.00	6.00	6.50	5.40	7.00	6.00	5.00	9.00
08/26/69										
CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/27/69										
CONC	6.80	8.20	5.70	5.20	5.50	5.40	8.00	4.90	4.00	8.10
08/28/69										
CONC	5.90	9.00	5.60	5.30	6.60	5.90	9.00	5.00	3.90	8.40
08/29/69										
CONC	6.00	6.90	5.20	5.00	6.00	6.00	9.20	4.90	3.90	6.90
09/01/69										
CONC	0.00	7.80	5.10	5.10	8.30	8.20	12.00	4.70	3.60	0.00
09/04/69										
CONC	10.00	10.00	6.20	6.40	8.00	12.00	15.00	3.60	4.10	10.00
09/08/69										
CONC	7.70	7.50	6.90	5.80	6.80	12.00	12.00	3.30	4.40	9.30
09/09/69										
CONC	6.60	6.00	5.20	4.00	6.80	9.00	11.00	3.90	5.10	7.90
09/11/69										
CONC	7.20	4.70	4.00	5.20	5.00	11.00	15.00	3.90	5.80	11.00
09/12/69										
CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69										
CONC	3.30	7.60	3.80	3.30	8.50	12.00	13.00	2.10	1.80	10.00
09/16/69										
CONC	7.20	13.00	7.00	5.90	10.00	0.00	0.00	0.00	4.10	13.00
09/17/69										
CONC	8.50	7.40	4.80	5.30	7.90	12.00	6.50	4.30	3.80	7.60
09/18/69										
CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix C Continued

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VARIABLE . . .    SODIUM
 DATE           S-10      S-20      S-22      S-26      S-38      S-40      S-52      T-20      M-20      W-02

09/19/69
     CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/22/69
     CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/23/69
     CONC       0.00      3.90      3.70      3.80      5.70      8.20     13.00      3.60      4.20      3.60
09/24/69
     CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/25/69
     CONC       0.00      4.40      4.00      4.50      6.8C      8.40     14.00      0.00      5.20     13.00
09/26/69
     CONC       0.00      0.00      0.00      4.20      5.50      9.50     10.00      4.20      4.20      0.00
09/29/69
     CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/30/69
     CONC       5.20      5.30      5.10      5.50      6.50      9.50     10.00      4.80      5.10     10.00
10/01/69
     CONC       0.00      5.70      5.30      5.70      0.00      0.00      0.00      0.00      0.00      0.00
10/02/69
     CONC       5.90      6.80      5.40      5.70      6.50      4.80      0.00      0.00      0.00     11.00
10/07/69
     CONC       6.90      7.40      6.00      6.10      8.40     11.00     10.00      5.00      5.10     10.00
10/09/69
     CONC       0.00      0.00      0.00     12.00     13.00     16.00     20.00     10.00      9.00      0.00
10/14/69
     CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
10/16/69
     CONC       0.00      9.50      7.00      7.50      9.50     13.00     14.00      7.00      5.20      0.00
10/20/69
     CONC       8.00      8.00      7.20      7.40      8.00      8.00      8.00      6.70      5.90      8.00
10/21/69
     CONC       9.70     10.00      8.40      0.00      9.80     10.00     10.00      8.50      6.20     10.00
10/23/69
     CONC      17.00     14.00      8.20     11.00     17.00     17.00     17.00      0.00      6.70      0.00
10/27/69
     CONC      22.00     19.00     16.00      0.00     30.00      0.00      0.00     15.00      0.30      5.90
10/28/69
     CONC      11.00     14.00      9.80      0.00     14.00     18.00     24.00     11.00      5.60     17.00
10/29/69
     CONC      13.00     14.00     13.00      0.00      0.00      0.00      0.00      0.00      0.00     16.00
11/03/69
     CONC      40.00     23.00      0.00     20.00     75.00     75.00     75.00     14.00      5.80      0.00
11/04/69
     CONC      13.00     12.00     10.00     12.00     13.00     14.00     16.00     12.00      9.80     15.00
11/10/69
     CONC      15.00     17.00     16.00      0.00      0.00      0.00      0.00      0.00      0.00     19.00
11/11/69
     CONC      13.00     15.00     15.00     13.00     10.00     13.00     12.00      7.50      8.50     18.00
11/12/69
     CONC       0.00     13.00     12.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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Appendix D. Magnesium Concentration Mg/L

VARIABLE . . . DATE		MAGNESIUM S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
07/07/69	CONC	14.00	10.00	10.00	23.00	21.00	29.00	23.00	21.00	10.00	18.00
07/08/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/09/69	CONC	22.00	15.00	15.00	14.00	14.00	16.00	15.00	9.50	12.00	28.00
07/10/69	CONC	15.00	17.00	16.00	13.00	15.00	17.00	17.00	13.00	13.00	30.00
07/11/69	CONC	15.00	17.00	16.00	3.00	15.00	17.00	17.00	14.00	14.00	31.00
07/14/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/15/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/16/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/17/69	CONC	18.00	18.00	18.00	17.00	19.00	18.00	18.00	17.00	17.00	32.00
07/18/69	CONC	0.00	0.00	0.00	0.00	22.00	0.00	0.00	0.00	0.00	0.00
07/21/69	CONC	14.00	13.00	13.00	18.00	0.00	22.00	17.00	0.00	9.00	30.00
07/22/69	CONC	13.00	21.00	19.00	12.00	10.00	17.00	15.00	7.00	12.00	35.00
07/23/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/24/69	CONC	15.00	12.00	12.00	11.00	11.00	13.00	15.00	11.00	13.00	36.00
07/25/69	CONC	13.00	53.00	13.00	14.00	19.00	19.00	19.00	19.00	16.00	35.00
07/28/69	CONC	17.00	18.00	17.00	19.00	23.00	22.00	16.00	22.00	18.00	37.00
07/29/69	CONC	17.00	18.00	19.00	21.00	25.00	24.00	25.00	23.00	20.00	37.00
07/30/69	CONC	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/31/69	CONC	0.00	20.00	22.00	25.00	29.00	24.00	27.00	26.00	21.00	37.00
08/01/69	CONC	23.00	21.00	22.00	28.00	28.00	29.00	29.00	27.00	21.00	30.00
08/04/69	CONC	24.00	25.00	25.00	24.00	28.00	29.00	30.00	15.00	23.00	32.00
08/05/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/06/69	CONC	23.00	26.00	26.00	26.00	24.00	31.00	31.00	18.00	24.00	28.00
08/07/69	CONC	23.00	26.00	26.00	27.00	26.00	35.00	31.00	16.00	24.00	26.00
08/08/69	CONC	25.00	26.00	25.00	30.00	30.00	0.00	30.00	19.00	26.00	28.00

Appendix D Continued

VARIABLE . . . MAGNESIUM DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	T-26	[illegible]
08/11/69 CONC	27.00	27.00	28.00	30.00	33.00	33.00	32.00	20.00	27.00	31.00
08/12/69 CONC	28.00	28.00	28.00	29.00	34.00	35.00	31.00	21.00	22.00	31.00
08/13/69 CONC	27.00	28.00	28.00	0.00	35.00	33.00	29.00	21.00	26.00	32.00
08/14/69 CONC	26.00	27.00	0.00	26.00	25.00	36.00	30.00	22.00	26.00	34.00
08/15/69 CONC	28.00	29.00	29.00	28.00	36.00	36.00	29.00	24.00	26.00	34.00
08/18/69 CONC	30.00	26.00	27.00	32.00	35.00	34.00	25.00	26.00	26.00	34.00
08/19/69 CONC	30.00	29.00	29.00	33.00	34.00	33.00	28.00	28.00	28.00	41.00
08/20/69 CONC	0.00	31.00	31.00	0.00	31.00	28.00	16.00	31.00	28.00	45.00
08/21/69 CONC	30.00	38.00	40.00	42.00	20.00	16.00	12.00	42.00	32.00	45.00
08/22/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/25/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/26/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/27/69 CONC	20.00	21.00	20.00	21.00	25.00	22.00	24.00	23.00	30.00	36.00
08/28/69 CONC	18.00	20.00	20.00	20.00	27.00	23.00	24.00	22.00	30.00	35.00
08/29/69 CONC	19.00	21.00	20.00	21.00	28.00	25.00	27.00	22.00	30.00	34.00
09/01/69 CONC	0.00	23.00	23.00	22.00	32.00	30.00	19.00	26.00	31.00	0.00
09/04/69 CONC	29.00	32.00	33.00	34.00	41.00	48.00	43.00	17.00	46.00	54.00
09/08/69 CONC	29.00	31.00	32.00	27.00	27.00	37.00	29.00	16.00	16.00	48.00
09/09/69 CONC	25.00	31.00	28.00	19.00	26.00	26.00	25.00	19.00	16.00	50.00
09/11/69 CONC	43.00	26.00	24.00	27.00	26.00	35.00	31.00	19.00	21.00	65.00
09/12/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69 CONC	23.00	26.00	25.00	25.00	29.00	33.00	32.00	21.00	27.00	38.00
09/16/69 CONC	24.00	28.00	27.00	24.00	34.00	34.00	31.00	0.00	26.00	38.00
09/17/69 CONC	21.00	19.00	17.00	24.00	31.00	33.00	15.00	16.00	16.00	32.00
09/18/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D Continued

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VARIABLE . . . MAGNESIUM
 DATE          S-10      S-20      S-22      S-26      S-38      S-40      S-52      T-20      H-20      W-02

09/19/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 .    0.00
09/22/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/23/69
    CONC       0.00     17.00     17.00     18.00     26.00     29.00     27.00     20.00     20.00     16.00
09/24/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/25/69
    CONC       0.00     18.00     19.00     20.00     28.00     25.00     28.00      0.00     19.00     32.00
09/26/69
    CONC       0.00      0.00      0.00     23.00     27.00     30.00     28.00     21.00     19.00      0.00
09/29/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/30/69
    CONC      24.00     25.00     25.00     28.00     30.00     30.00     29.00     24.00     20.00     40.00
10/01/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
10/02/69
    CONC      28.00     29.00     29.00     33.00     36.00     37.00      0.00      0.00      0.00     38.00
10/07/69
    CONC      28.00     29.00     29.00     33.00     36.00     36.00     30.00     29.00     25.00     45.00
10/09/69
    CONC       0.00     29.00      0.00     37.00     41.00     39.00     33.00     34.00     29.00      0.00
10/14/69
    CONC      28.00      0.00     29.00     31.00     34.00     32.00     33.00     32.00     29.00     42.00
10/16/69
    CONC       0.00     33.00     33.00     35.00     38.00     36.00     36.00     34.00     31.00      0.00
10/20/69
    CONC      33.00     33.00     34.00     35.00     39.00     39.00     33.00     33.00     29.00     47.00
10/21/69
    CONC      32.00     33.00     34.00      0.00     40.00     40.00     30.00     36.00     29.00     40.00
10/23/69
    CONC      49.00     49.00     49.00     49.00     62.00     61.00     54.00     56.00     51.00      0.00
10/27/69
    CONC      36.00     36.00     37.00      0.00     41.00      0.00      0.00     38.00     50.00     32.00
10/28/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
10/29/69
    CONC      38.00     47.00     41.00      0.00      0.00      0.00      0.00      0.00      0.00     52.00
11/03/69
    CONC      39.00     38.00      0.00     39.00     39.00     35.00     26.00     27.00     19.00     52.00
11/04/69
    CONC      39.00     40.00     39.00     41.00     38.00     35.00     27.00     41.00     23.00     52.00
11/10/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
11/11/69
    CONC      35.00     28.00     28.00     35.00     32.00     31.00     29.00     28.00     24.00     48.00
11/12/69
    CONC       0.00     30.00     31.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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Appendix E. Calcium Concentration Mg/L

VARIABLE . . .		CALCIUM									
DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	H-02
07/07/69	CONC	49.00	44.00	44.00	112.00	130.00	150.00	88.00	104.00	38.00	90.00
07/08/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/09/69	CONC	19.00	10.00	10.00	7.00	7.00	10.00	14.00	5.00	10.00	21.00
07/10/69	CONC	15.00	16.00	16.00	14.00	13.00	17.00	20.00	13.00	18.00	20.00
07/11/69	CONC	18.00	18.00	18.00	17.10	29.00	24.00	24.00	22.00	19.00	31.00
07/14/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/15/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/16/69	CONC	91.00	80.00	68.00	79.00	79.00	86.00	83.00	65.00	68.00	67.00
07/17/69	CONC	15.00	18.00	18.00	13.00	14.00	17.00	24.00	16.00	18.00	18.00
07/18/69	CONC	0.00	0.00	0.00	0.00	88.00	0.00	0.00	0.00	0.00	0.00
07/21/69	CONC	58.00	56.00	56.00	73.00	0.00	105.00	0.00	0.00	38.00	66.00
07/22/69	CONC	52.00	80.00	75.00	48.00	45.00	70.00	66.00	40.00	48.00	70.00
07/23/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/24/69	CONC	64.00	49.00	49.00	24.00	30.00	52.00	55.00	35.00	52.00	0.00
07/25/69	CONC	52.00	13.80	48.00	53.00	69.00	77.00	74.00	65.00	60.00	70.00
07/28/69	CONC	62.00	67.00	68.00	78.00	90.00	92.00	56.00	87.00	74.00	72.00
07/29/69	CONC	66.00	74.00	79.00	87.00	105.00	108.00	95.00	95.00	80.00	75.00
07/30/69	CONC	60.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/31/69	CONC	0.00	60.00	72.00	77.00	100.00	90.00	95.00	95.00	70.00	65.00
08/01/69	CONC	80.00	80.00	75.00	95.00	95.00	88.00	0.00	99.00	76.00	70.00
08/04/69	CONC	76.00	76.00	83.00	74.00	99.00	104.00	93.00	55.00	80.00	76.00
08/05/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/06/69	CONC	56.00	77.00	77.00	77.00	87.00	115.00	102.00	68.00	88.00	70.00
08/07/69	CONC	50.00	68.00	68.00	72.00	87.00	106.00	92.00	62.00	81.00	63.00
08/08/69	CONC	54.00	62.00	61.00	70.00	85.00	101.00	86.00	59.00	72.00	55.00

Appendix E Continued

VARIABLE . . . CALCIUM

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-52
08/11/69	CONC	60.00	74.00	74.00	88.00	114.00	122.00	101.00	76.00	76.00	74.00
08/12/69	CONC	72.00	72.00	67.00	82.00	117.00	120.00	101.00	74.00	75.00	56.00
08/13/69	CONC	66.00	77.00	82.00	0.00	115.00	107.00	86.00	75.00	76.00	57.00
08/14/69	CONC	70.00	80.00	0.00	76.00	112.00	112.00	87.00	94.00	75.00	55.00
08/15/69	CONC	70.00	84.00	83.00	77.00	105.00	112.00	91.00	87.00	72.00	53.00
08/18/69	CONC	82.00	82.00	82.00	89.00	113.00	117.00	87.00	99.00	76.00	60.00
08/19/69	CONC	83.00	84.00	83.00	100.00	117.00	117.00	70.60	105.00	68.00	59.00
08/20/69	CONC	0.00	87.00	83.00	107.00	108.00	83.00	63.00	108.00	73.00	63.00
08/21/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/22/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/25/69	CONC	80.00	58.00	59.00	65.00	73.00	70.00	68.00	70.00	71.00	59.00
08/26/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/27/69	CONC	63.00	65.00	64.00	68.00	85.00	88.00	80.00	75.00	72.00	53.00
08/28/69	CONC	62.00	56.00	58.00	59.00	86.00	86.00	81.00	68.00	77.00	49.00
08/29/69	CONC	58.00	73.00	68.00	78.00	112.00	92.00	0.00	67.00	66.00	48.00
09/01/69	CONC	0.00	46.00	60.00	72.00	112.00	115.00	0.00	79.00	78.00	0.00
09/04/69	CONC	50.00	43.00	53.00	64.00	98.00	126.00	0.00	24.00	62.00	38.00
09/08/69	CONC	48.00	67.00	70.00	55.00	65.00	103.00	66.00	31.00	24.00	34.00
09/09/69	CONC	91.10	115.00	105.00	78.60	102.00	118.00	115.00	80.40	63.00	66.00
09/11/69	CONC	131.00	87.00	82.20	96.40	89.20	145.00	115.00	73.00	74.00	63.00
09/12/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69	CONC	72.00	88.00	82.00	94.00	122.00	152.00	0.00	78.00	77.00	50.00
09/16/69	CONC	85.00	85.00	84.00	85.00	115.00	138.00	115.00	0.00	76.00	65.00
09/17/69	CONC	73.00	64.00	50.00	81.00	100.00	123.00	55.00	64.00	50.00	45.00
09/18/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix E Continued

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VARIABLE . . .    CALCIUM
 DATE          S-10      S-20      S-22      S-26      S-38      S-40      S-52      T-20      M-20      W-02

09/19/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/22/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/23/69
    CONC       0.00     65.00     60.00     65.00     97.00    113.00    100.00     76.00     77.00     60.00
09/24/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/25/69
    CONC       0.00     63.00     70.00     75.00    102.00    101.00    108.00      0.00     79.00     67.00
09/26/69
    CONC       0.00      0.00      0.00     88.00    103.00    135.00    110.00    101.00     74.00      0.00
09/29/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/30/69
    CONC     100.00    130.00    104.00    121.00    120.00    114.00    122.00    102.00     84.00     77.00
10/01/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
10/02/69
    CONC      79.00     84.00     83.00     84.00     91.00      0.00      0.00      0.00      0.00     69.00
10/07/69
    CONC      81.00     81.00     82.00     84.00    131.00    150.00    110.00    105.00     82.00     62.00
10/09/69
    CONC       0.00     71.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
10/14/69
    CONC      71.00      0.00     72.00    100.00    100.00    115.00    100.00    115.00     76.00     74.00
10/16/69
    CONC       0.00    106.00    107.00    120.00    130.00    135.00    125.00    120.00     87.00      0.00
10/20/69
    CONC     103.00    109.00    111.00    118.00    135.00    150.00    115.00    118.00     84.00     76.00
10/21/69
    CONC     106.00    109.00    110.00      0.00    132.00    135.00    106.00    125.00     88.00     75.00
10/23/69
    CONC     200.00    200.00    204.00     23.00    295.00    575.00    200.00    300.00    200.00      0.00
10/27/69
    CONC     114.00    120.00    122.00      0.00    140.00      0.00      0.00    128.00     75.00     88.00
10/28/69
    CONC      11.00    118.00    118.00      0.00    142.00    142.00    141.00    134.00    114.00     94.00
10/29/69
    CONC     120.00    130.00    132.00      0.00      0.00      0.00      0.00      0.00      0.00     75.00
11/03/69
    CONC     122.00    127.00      0.00    145.00    155.00    155.00    110.00    136.00     85.00     75.00
11/04/69
    CONC     120.00    130.00    128.00    140.00    130.00    125.00    105.00    135.00     85.00     75.00
11/10/69
    CONC       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
11/11/69
    CONC     117.00     98.00     90.00     96.00     98.00    104.00    100.00     98.00     79.00     79.00
11/12/69
    CONC       0.00    100.00    104.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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Appendix F. Total Phosphorus Concentration Mg/L

VARIABLE . . . TOTAL PHOSPHATE

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
04/03/69	CONC	0.00	0.00	0.00	0.15	0.18	0.20	0.18	0.09	0.00	0.00
04/04/69	CONC	0.21	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/10/69	CONC	0.00	0.00	0.00	0.29	0.29	0.29	0.29	0.29	0.00	0.00
04/11/69	CONC	0.33	0.35	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/17/69	CONC	0.00	0.00	0.00	0.21	0.22	0.28	0.32	0.12	0.00	0.00
04/18/69	CONC	0.23	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/24/69	CONC	0.00	0.00	0.00	0.30	0.32	0.29	0.29	0.20	0.00	0.00
04/25/69	CONC	0.27	0.24	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/01/69	CONC	0.00	0.00	0.00	0.19	0.26	0.49	0.22	0.12	0.00	0.00
05/02/69	CONC	0.25	0.31	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/08/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/09/69	CONC	0.24	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/15/69	CONC	0.33	0.35	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/23/69	CONC	0.00	0.00	0.00	0.27	0.29	0.32	0.29	0.29	0.00	0.00
05/27/69	CONC	0.25	0.28	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/28/69	CONC	0.00	0.00	0.00	0.22	0.27	0.27	0.30	0.20	0.00	0.00
06/05/69	CONC	0.35	0.38	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/06/69	CONC	0.00	0.00	0.00	0.29	0.34	0.38	0.49	0.21	0.00	0.00
06/12/69	CONC	0.23	0.24	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/13/69	CONC	0.00	0.00	0.00	0.34	0.31	0.49	0.49	0.18	0.00	0.00
06/19/69	CONC	0.33	0.45	0.30	0.30	0.42	0.00	0.47	0.28	0.00	0.00
06/26/69	CONC	0.39	0.42	0.26	0.31	0.30	0.46	0.61	0.32	0.00	0.00
06/30/69	CONC	0.39	0.62	0.47	0.41	0.45	0.56	0.54	0.32	0.21	0.20
07/01/69	CONC	0.38	0.38	0.55	0.35	0.45	0.51	0.70	0.28	0.20	0.19
07/02/69	CONC	0.51	0.50	0.35	0.34	0.41	0.46	0.51	0.26	0.20	0.19
07/03/69	CONC	0.95	0.50	0.31	0.30	0.42	0.46	0.75	0.22	0.19	0.18

Appendix F Continued

VARIABLE . . . TOTAL PHOSPHATE										
DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
07/07/69										
CONC	0.00	0.00	0.00	0.34	0.51	0.65	0.75	0.25	0.00	0.40
07/08/69										
CONC	0.41	0.17	0.15	0.44	0.17	0.44	0.19	0.00	0.03	0.28
07/09/69										
CONC	0.50	0.82	0.79	0.91	0.62	0.52	0.00	0.66	0.31	0.25
07/10/69										
CONC	0.68	0.55	0.51	0.53	0.44	0.45	0.44	0.39	0.29	0.24
07/11/69										
CONC	0.67	0.57	0.56	0.45	0.42	0.42	0.39	0.31	0.25	0.20
07/14/69										
CONC	0.52	0.52	0.47	0.41	0.52	0.76	0.57	0.45	0.45	0.21
07/15/69										
CONC	0.44	0.52	0.44	0.41	0.57	0.56	0.52	0.71	0.36	0.17
07/16/69										
CONC	0.52	0.53	0.47	0.47	0.59	0.52	0.54	0.53	0.34	0.10
07/17/69										
CONC	0.08	0.48	0.37	0.39	0.44	0.48	0.48	0.33	0.16	0.07
07/18/69										
CONC	0.51	0.52	0.36	0.31	0.48	0.48	0.56	0.34	0.32	0.15
07/21/69										
CONC	0.64	0.78	0.68	0.44	0.70	0.40	0.48	0.80	0.60	0.28
07/22/69										
CONC	0.76	0.60	0.60	1.30	1.10	1.10	1.10	0.74	0.34	0.20
07/23/69										
CONC	1.30	1.10	1.00	1.00	0.68	1.00	1.00	0.54	0.00	0.32
07/24/69										
CONC	1.10	0.93	0.82	0.66	0.56	0.76	0.71	0.43	0.33	0.22
07/25/69										
CONC	0.62	0.59	0.50	0.51	0.50	0.65	0.77	0.36	0.31	0.26
07/28/69										
CONC	0.50	0.58	4.00	0.39	0.43	0.56	0.53	0.58	0.27	0.22
07/29/69										
CONC	0.57	0.49	0.38	0.36	0.49	0.50	0.65	0.28	0.28	0.20
07/30/69										
CONC	0.56	0.51	0.38	0.40	0.44	0.54	0.74	0.26	0.26	0.20
07/31/69										
CONC	0.51	0.50	0.36	0.36	0.47	0.51	0.88	0.26	0.25	0.36
08/01/69										
CONC	0.49	0.49	0.33	0.34	0.45	0.50	0.78	0.22	0.21	0.17
08/04/69										
CONC	0.36	0.41	0.30	0.32	0.41	0.50	0.72	0.28	0.25	0.25
08/05/69										
CONC	0.31	0.50	0.31	0.25	0.39	0.52	0.90	0.38	0.18	0.17
08/06/69										
CONC	0.30	0.43	0.35	0.31	0.46	0.56	1.00	0.36	0.21	0.17
08/07/69										
CONC	0.36	0.46	0.27	0.27	0.45	0.52	0.93	0.32	0.17	0.16
08/08/69										
CONC	0.38	0.42	0.24	0.26	0.51	0.54	0.99	0.33	0.17	0.16

Appendix F Continued

VARIARLE . . . TOTAL PHOSPHATE

DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
08/11/69 CONC	0.32	0.43	0.24	0.24	0.51	0.65	0.81	0.27	0.08	0.10
08/12/69 CONC	0.42	0.72	0.23	0.22	0.58	0.68	0.99	0.24	0.06	0.08
08/13/69 CONC	0.36	0.48	0.23	0.00	0.62	0.70	0.99	0.16	0.11	0.16
08/14/69 CONC	0.38	0.52	0.00	0.22	0.50	0.49	0.70	0.21	0.13	0.15
08/15/69 CONC	0.38	0.47	0.18	0.19	0.44	0.52	1.20	0.19	0.13	0.14
08/18/69 CONC	0.38	0.51	0.25	0.24	0.00	0.28	0.82	0.19	0.11	0.13
08/19/69 CONC	0.44	0.60	0.24	0.23	0.66	0.77	1.10	0.19	0.15	0.14
08/20/69 CONC	0.39	0.58	0.23	0.29	0.93	1.00	1.30	0.19	0.14	0.11
08/21/69 CONC	0.45	0.39	0.30	0.33	1.30	1.10	1.00	0.22	0.13	0.13
08/22/69 CONC	0.65	0.37	0.38	0.62	0.55	0.70	0.72	0.31	0.11	0.14
08/25/69 CONC	0.43	0.42	0.60	0.38	0.47	0.59	0.78	0.30	0.61	0.14
08/26/69 CONC	0.39	0.69	0.42	0.54	0.58	0.54	1.20	0.54	0.13	0.17
08/27/69 CONC	0.40	0.68	0.44	0.31	0.51	0.68	0.92	0.27	0.10	0.13
08/28/69 CONC	0.40	0.81	0.29	0.27	0.61	0.60	0.96	0.22	0.11	0.13
08/29/69 CONC	0.38	0.75	0.26	0.27	0.57	0.65	1.30	0.20	0.13	0.13
09/01/69 CONC	0.00	0.85	0.27	0.21	0.52	0.58	1.10	0.18	0.13	0.00
09/04/69 CONC	0.43	0.66	0.24	0.14	0.34	0.00	1.10	0.54	1.10	0.07
09/08/69 CONC	0.22	0.00	0.00	0.74	0.56	0.78	0.75	0.27	0.56	0.11
09/09/69 CONC	0.50	0.34	0.22	0.27	0.47	0.60	0.96	0.43	0.34	0.13
09/11/69 CONC	0.46	0.37	0.26	0.24	0.38	0.27	1.20	0.30	0.20	0.10
09/12/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69 CONC	0.38	0.68	0.18	0.33	0.52	0.64	1.20	0.26	0.11	0.08
09/16/69 CONC	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
09/17/69 CONC	0.37	0.88	0.26	0.24	0.88	0.60	1.30	0.22	0.47	0.06
09/18/69 CONC	0.00	0.00	0.31	0.00	0.61	0.77	1.50	0.66	0.55	0.22

Appendix F Continued

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VARIABLE . . . TOTAL PHOSPHATE
 DATE          S-10       S-20       S-22       S-26       S-38       S-40       S-52       T-20       H-20       W-02

09/19/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/22/69
     CONC      0.46       0.55       0.39       0.09       0.37       0.34       0.51       0.10       0.39       0.12
09/23/69
     CONC      0.00       0.57       0.45       0.37       0.39       0.00       0.00       0.00       0.37       0.44
09/24/69
     CONC      0.43       0.75       0.52       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/25/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/26/69
     CONC      0.00       0.00       0.00       0.28       0.28       0.49       0.70       0.19       0.19       0.00
09/29/69
     CONC      0.34       0.37       0.25       0.29       0.49       0.28       0.49       0.17       0.00       0.00
09/30/69
     CONC      0.00       0.70       0.28       0.24       0.29       0.50       1.10       0.17       0.12       0.15
10/01/69
     CONC      0.00       0.62       0.20       0.67       0.00       0.00       0.00       0.00       0.00       0.00
10/02/69
     CONC      0.00       0.46       0.19       0.20       0.33       9.50       0.00       0.00       0.00       0.04
10/07/69
     CONC      0.27       0.41       0.40       0.33       0.97       0.41       0.94       0.11       0.09       0.05
10/09/69
     CONC      0.00       0.93       0.00       0.19       0.23       0.48       1.20       0.10       0.09       0.00
10/14/69
     CONC      0.30       0.00       0.22       0.00       0.28       0.72       1.20       0.35       0.07       0.18
10/16/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/20/69
     CONC      0.42       0.57       0.17       0.16       0.48       0.00       0.88       0.12       0.12       0.05
10/21/69
     CONC      0.30       0.72       0.07       0.00       4.40       0.56       2.20       1.10       0.17       0.06
10/23/69
     CONC      0.36       0.42       0.11       0.37       0.00       0.00       0.00       0.00       0.00       0.05
10/27/69
     CONC      0.00       0.45       0.13       0.00       0.52       0.00       0.00       0.08       0.04       0.07
10/28/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
10/29/69
     CONC      0.31       0.34       0.11       0.00       0.00       0.00       0.00       0.00       0.00       0.09
11/03/69
     CONC      0.00       0.43       0.00       0.31       0.57       0.00       0.00       0.00       0.00       0.12
11/04/69
     CONC      0.59       0.42       0.18       0.32       0.47       0.00       0.12       0.25       0.28       0.11
11/10/69
     CONC      0.37       0.40       0.49       0.00       0.00       0.00       0.00       0.00       0.00       0.16
11/11/69
     CONC      0.34       0.57       0.42       0.26       0.28       0.44       0.54       0.05       0.09       0.15
11/12/69
     CONC      0.00       0.29       0.57       0.00       0.00       0.00       0.00       0.00       0.00       0.00
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Appendix F Continued

VARIABLE . . . TOTAL PHOSPHATE

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
11/13/69	CONC	0.00	0.00	0.00	0.78	0.37	0.42	0.73	0.08	0.24	0.00
11/17/69	CONC	0.37	0.34	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.09
11/18/69	CONC	0.35	0.41	0.21	0.25	0.40	0.59	0.73	0.05	0.16	0.08
11/19/69	CONC	0.47	0.25	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.36
11/20/69	CONC	0.00	0.00	0.00	0.61	0.42	0.33	0.70	0.40	0.25	0.00
11/24/69	CONC	0.24	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
11/25/69	CONC	0.00	0.00	0.00	0.18	0.26	0.21	0.23	0.16	0.12	0.00
12/02/69	CONC	0.00	0.00	0.00	0.16	0.23	0.23	0.37	0.16	0.13	0.00
12/04/69	CONC	0.21	0.26	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/19/69	CONC	0.00	0.00	0.00	0.16	0.19	0.00	0.27	0.08	0.08	0.00
01/06/70	CONC	0.29	0.00	0.00	0.26	0.00	0.00	0.63	0.03	0.00	0.00
01/14/70	CONC	0.00	0.00	0.00	0.32	0.54	0.63	0.67	0.03	0.10	0.00
01/20/70	CONC	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00
01/21/70	CONC	0.37	0.40	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/26/70	CONC	0.00	0.00	0.00	0.00	0.56	0.64	0.64	0.07	0.16	0.00
01/29/70	CONC	0.37	0.46	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/02/70	CONC	0.49	0.51	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.33
02/05/70	CONC	0.00	0.00	0.00	0.28	0.26	0.23	0.23	0.29	0.21	0.00
02/12/70	CONC	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/13/70	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/18/70	CONC	0.16	0.24	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.10
02/19/70	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/20/70	CONC	0.00	0.00	0.00	0.17	0.00	0.21	0.22	0.00	0.09	0.00
02/24/70	CONC	0.00	0.00	0.00	0.24	0.27	0.25	0.27	0.18	0.00	0.00
02/26/70	CONC	0.23	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix G. Soluble Orthophosphorus Mg/L

VARIABLE . . .		ORTHO PHOSPHATE									
DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
07/07/69	CONC	0.06	0.05	0.09	0.07	0.21	0.26	0.28	0.03	0.07	0.06
07/08/69	CONC	0.09	0.09	0.07	0.16	0.09	0.11	0.12	0.23	0.07	0.09
07/09/69	CONC	0.17	0.10	0.08	0.09	0.09	0.12	0.11	0.06	0.05	0.06
07/10/69	CONC	0.10	0.13	0.09	0.08	0.09	0.13	0.13	0.06	0.06	0.05
07/11/69	CONC	0.10	0.11	0.08	0.09	0.10	0.15	0.14	0.05	0.06	0.03
07/14/69	CONC	0.10	0.15	0.08	0.12	0.11	0.14	0.16	0.05	0.06	0.00
07/15/69	CONC	0.11	0.23	0.14	0.13	0.12	0.18	0.17	0.08	0.07	0.00
07/16/69	CONC	0.18	0.20	0.11	0.11	0.14	0.17	0.21	0.07	0.07	0.00
07/17/69	CONC	0.17	0.21	0.09	0.16	0.17	0.18	0.23	0.06	0.06	0.00
07/18/69	CONC	0.18	0.21	0.08	0.12	0.20	0.21	0.30	0.06	0.07	0.01
07/21/69	CONC	0.12	0.14	0.09	0.12	0.11	0.23	0.18	0.00	0.06	0.0R
07/22/69	CONC	0.11	0.18	0.11	0.22	0.20	0.20	0.14	0.19	0.06	0.01
07/23/69	CONC	0.20	0.20	0.18	0.19	0.15	0.21	0.23	0.13	0.05	0.00
07/24/69	CONC	0.17	0.12	0.12	0.14	0.15	0.21	0.22	0.10	0.05	0.00
07/25/69	CONC	0.16	0.19	0.13	0.15	0.16	0.21	0.26	0.08	0.06	0.00
07/28/69	CONC	0.19	0.35	0.11	0.16	0.16	0.24	0.25	0.06	0.06	0.03
07/29/69	CONC	0.20	0.27	0.12	0.15	0.17	0.25	0.29	0.06	0.06	0.03
07/30/69	CONC	0.21	0.28	0.12	0.14	0.11	0.14	0.14	0.05	0.06	0.04
07/31/69	CONC	0.26	0.28	0.11	0.14	0.09	0.00	0.42	0.05	0.06	0.04
08/01/69	CONC	0.25	0.28	0.11	0.11	0.06	0.02	0.29	0.05	0.07	0.04
08/04/69	CONC	0.10	0.02	0.00	0.00	0.05	0.01	0.20	0.05	0.06	0.02
08/05/69	CONC	0.00	0.00	0.00	0.00	0.10	0.03	0.35	0.06	0.05	0.00
08/06/69	CONC	0.00	0.02	0.00	0.00	0.06	0.05	0.42	0.06	0.05	0.01
08/07/69	CONC	0.00	0.13	0.00	0.00	0.10	0.09	0.52	0.06	0.03	0.00
08/08/69	CONC	0.02	0.20	0.00	0.02	0.13	0.05	0.58	0.06	0.03	0.00

Appendix G Continued

VARIABLE . . . ORTHO PHOSPHATE DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
08/11/69	CONC	0.06	0.29	0.04	0.02	0.14	0.11	0.44	0.04	0.02	0.01
08/17/69	CONC	0.08	0.58	0.05	0.03	0.13	0.13	0.58	0.04	0.03	0.02
08/13/69	CONC	0.10	0.32	0.04	0.00	0.18	0.18	0.55	0.03	0.03	0.03
08/14/69	CONC	0.11	0.35	0.00	0.03	0.14	0.08	0.54	0.03	0.03	0.01
08/15/69	CONC	0.11	0.33	0.02	0.03	0.14	0.12	0.69	0.03	0.02	0.01
08/18/69	CONC	0.16	0.27	0.02	0.05	0.22	0.26	0.42	0.02	0.02	0.02
08/19/69	CONC	0.13	0.40	0.04	0.06	0.26	0.30	0.66	0.01	0.02	0.01
08/20/69	CONC	0.12	0.43	0.03	0.08	0.43	0.43	0.38	0.01	0.03	0.02
08/21/69	CONC	0.10	0.09	0.05	0.08	0.37	0.35	0.23	0.01	0.03	0.02
08/22/69	CONC	0.17	0.15	0.06	0.25	0.18	0.23	0.25	0.05	0.02	0.02
08/25/69	CONC	0.10	0.12	0.32	0.12	0.19	0.23	0.43	0.13	0.04	0.02
08/26/69	CONC	0.12	0.43	0.07	0.10	0.21	0.25	0.54	0.04	0.02	0.02
08/27/69	CONC	0.11	0.36	0.04	0.06	0.21	0.21	0.60	0.02	0.01	0.02
08/28/69	CONC	0.11	0.47	0.01	0.02	0.26	0.18	0.60	0.01	0.01	0.02
08/29/69	CONC	0.17	0.40	0.01	0.02	0.17	0.16	0.83	0.01	0.02	0.02
09/01/69	CONC	0.00	0.65	0.02	0.03	0.18	0.10	0.63	0.00	0.01	0.00
09/04/69	CONC	0.24	0.49	0.03	0.02	0.06	0.22	0.70	0.07	0.00	0.04
09/08/69	CONC	0.10	0.00	0.00	0.09	0.26	0.35	0.42	0.07	0.21	0.06
09/09/69	CONC	0.26	0.20	0.05	0.09	0.20	0.28	0.56	0.06	0.14	0.06
09/11/69	CONC	0.20	0.15	0.06	0.08	0.14	0.26	1.10	0.10	0.08	0.06
09/12/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69	CONC	0.14	0.46	0.01	0.04	0.18	0.27	0.74	0.12	0.03	0.03
09/16/69	CONC	0.20	0.36	0.07	0.11	0.00	0.33	0.97	0.00	0.07	0.08
09/17/69	CONC	0.14	0.34	0.07	0.06	0.22	0.23	0.32	0.07	0.00	0.04
09/18/69	CONC	0.19	0.06	0.04	0.05	0.19	0.24	0.27	0.14	0.19	0.08

Appendix G Continued

VARIABLE . . . ORTHO PHOSPHATE

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
09/19/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/22/69	CONC	0.22	0.24	0.14	0.04	0.14	0.22	0.35	0.10	0.00	0.00
09/23/69	CONC	0.00	0.24	0.11	0.18	0.14	0.22	0.49	0.08	0.05	0.12
09/24/69	CONC	0.19	0.47	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/25/69	CONC	0.22	0.18	0.10	0.08	0.14	0.24	0.44	0.09	0.09	0.03
09/26/69	CONC	0.00	0.00	0.00	0.10	0.16	0.26	0.34	0.07	0.00	0.00
09/29/69	CONC	0.17	0.17	0.07	0.09	0.09	0.08	0.46	0.06	0.07	0.00
09/30/69	CONC	0.19	0.21	0.07	0.09	0.11	0.00	0.68	0.09	0.06	0.08
10/01/69	CONC	0.00	0.18	0.07	0.06	0.00	0.00	0.00	0.00	0.00	0.00
10/02/69	CONC	0.00	0.32	0.04	0.01	0.13	0.00	0.00	0.00	0.00	0.01
10/07/69	CONC	0.07	0.23	0.11	0.01	0.19	0.27	0.60	0.04	0.09	0.03
10/09/69	CONC	0.00	0.48	0.00	0.03	0.32	0.28	0.76	0.04	0.04	0.00
10/14/69	CONC	0.16	0.00	0.03	0.06	0.28	0.43	0.80	0.02	0.04	0.04
10/16/69	CONC	0.00	0.38	0.02	0.01	0.30	0.40	0.72	0.02	0.02	0.00
10/20/69	CONC	0.23	0.40	0.02	0.02	0.24	0.00	0.88	0.02	0.01	0.04
10/21/69	CONC	0.21	0.21	0.02	0.00	0.24	0.33	1.20	0.02	0.03	0.04
10/23/69	CONC	0.25	0.35	0.03	0.06	0.35	0.43	0.00	0.02	0.02	0.06
10/27/69	CONC	0.23	0.33	0.03	0.00	0.37	0.00	0.00	0.03	0.03	0.06
10/28/69	CONC	0.25	0.56	0.05	0.00	0.41	0.50	1.10	0.02	0.01	0.05
10/29/69	CONC	0.22	0.55	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.75
11/03/69	CONC	0.34	0.28	0.00	0.12	0.40	0.00	0.00	0.04	0.00	0.09
11/04/69	CONC	0.34	0.19	0.04	0.16	0.34	0.53	1.20	0.02	0.14	0.10
11/10/69	CONC	0.29	0.33	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.15
11/11/69	CONC	0.28	0.51	0.31	0.20	0.26	0.37	0.50	0.04	0.08	0.14
11/12/69	CONC	0.00	0.19	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix H. Nitrate-Nitrogen Concentration Mg/L

VARIABLE . . . DATE	NITRATE S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-2[illegible]	[illegible]	[illegible]
07/07/69 CONC	4.60	5.60	4.40	2.60	2.90	2.60	3.30	3.60	5.10	5.00
07/08/69 CONC	4.20	2.60	2.30	1.90	7.00	6.10	6.40	8.60	4.50	5.80
07/09/69 CONC	2.90	6.20	6.30	7.70	7.60	7.90	6.60	5.80	4.80	5.70
07/10/69 CONC	8.40	9.90	6.60	6.00	8.50	6.60	5.90	7.60	4.00	4.50
07/11/69 CONC	5.30	5.60	5.30	6.10	5.60	4.60	4.70	5.90	3.10	3.90
07/14/69 CONC	3.70	4.20	4.20	4.10	3.70	3.70	3.40	4.10	3.60	2.00
07/15/69 CONC	3.20	3.20	3.00	3.00	3.40	2.90	2.90	4.20	2.80	1.50
07/16/69 CONC	7.10	6.40	6.40	6.40	7.00	6.00	5.90	9.00	5.30	2.60
07/17/69 CONC	4.40	4.90	4.70	5.10	4.90	4.00	3.90	5.80	3.60	1.90
07/18/69 CONC	4.20	4.20	3.50	4.60	4.00	3.60	3.20	4.90	2.80	1.60
07/21/69 CONC	3.00	2.70	2.60	2.70	2.60	2.10	3.00	0.00	1.80	1.00
07/22/69 CONC	2.20	2.50	2.10	1.70	2.40	3.60	2.70	1.90	1.80	1.00
07/23/69 CONC	2.20	2.50	2.50	2.40	2.50	2.80	2.80	2.40	1.70	1.00
07/24/69 CONC	2.10	2.10	2.10	2.20	2.20	2.30	2.40	2.10	1.50	1.00
07/25/69 CONC	2.00	2.10	2.00	2.00	2.00	2.10	2.10	2.00	1.40	1.00
07/28/69 CONC	2.10	2.20	1.90	2.20	2.00	1.80	1.70	2.20	1.70	1.00
07/29/69 CONC	1.80	1.90	1.90	2.00	1.60	1.40	1.20	1.90	1.00	1.00
07/30/69 CONC	1.80	2.00	1.80	1.80	1.30	1.00	1.10	1.80	1.60	0.50
07/31/69 CONC	2.50	2.60	2.70	2.30	1.50	1.00	1.70	0.24	2.40	0.50
08/01/69 CONC	2.40	2.30	2.00	1.80	0.50	2.10	0.90	2.30	2.20	1.50
08/04/69 CONC	1.00	0.50	0.50	4.00	1.10	1.00	0.50	1.50	2.00	0.50
08/05/69 CONC	1.10	0.50	0.50	4.00	1.70	1.00	0.80	2.00	3.10	0.50
08/06/69 CONC	1.00	0.50	0.50	1.00	1.20	1.00	0.90	2.10	3.10	0.50
08/07/69 CONC	0.50	0.50	0.50	1.00	1.20	1.00	0.50	2.20	3.10	0.50
08/08/69 CONC	0.50	0.50	0.50	1.00	0.50	1.00	0.50	1.60	2.60	0.50

Appendix H Continued

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VARIABLE . . .     NITRATE
 DATE          S-10       S-20       S-22       S-26       S-38       S-40       S-52       T-20       H-20       W-02

08/11/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       1.40       2.80       0.50
08/12/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       1.20       2.60       0.50
08/13/69
     CONC      0.50       0.50       0.50       0.00       0.50       1.00       0.50       1.00       2.70       0.50
08/14/69
     CONC      0.50       0.50       0.00       1.00       0.50       1.00       0.50       0.50       2.60       0.50
08/15/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       0.50       2.30       0.50
08/18/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       0.50       1.90       0.50
08/19/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       0.00       0.00       0.50
08/20/69
     CONC      0.50       0.50       0.50       1.00       0.50       1.00       0.50       0.00       0.00       0.50
08/21/69
     CONC      0.00       0.00       0.00       0.00       0.00       1.00       0.50       0.00       0.00       0.50
08/22/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.50
08/25/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
08/26/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
08/27/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
08/28/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
08/29/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/01/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/04/69
     CONC      0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/08/69
     CONC      0.00       0.00       0.00       2.10       3.10       1.70       2.80       3.60       4.80       1.20
09/09/69
     CONC      2.10       0.50       0.50       1.00       0.50       1.00       0.50       0.50       2.40       0.50
09/11/69
     CONC      0.00       1.50       0.00       1.10       1.50       1.00       0.50       1.70       5.10       1.70
09/12/69
     CONC      0.00       0.50       1.30       1.00       0.00       0.00       0.00       0.00       0.00       0.00
09/15/69
     CONC      0.50       1.30       0.50       1.00       0.50       1.00       0.50       1.90       4.60       0.50
09/16/69
     CONC      0.50       1.00       0.50       1.00       0.50       1.00       0.50       0.00       0.00       3.50
09/17/69
     CONC      1.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
09/18/69
     CONC      0.00       1.00       0.50       1.00       2.10       1.00       1.50       1.30       3.90       0.50
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Appendix H Continued

VARIABLE . . . NITRATE

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
09/19/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/22/69	CONC	4.20	0.00	0.00	3.70	3.00	0.00	2.30	0.00	6.80	1.10
09/23/69	CONC	0.00	4.00	3.80	0.00	3.00	2.20	2.30	3.00	0.00	0.00
09/24/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/25/69	CONC	0.00	4.20	4.00	3.40	4.00	2.30	2.40	3.60	6.10	4.30
09/26/69	CONC	0.00	0.00	0.00	2.30	3.20	1.80	1.70	2.70	4.20	0.00
09/29/69	CONC	6.70	6.60	5.90	6.40	2.90	6.30	6.70	6.30	7.20	0.00
09/30/69	CONC	3.10	2.90	2.80	2.50	1.60	1.00	1.20	1.90	2.80	4.10
10/01/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/02/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/07/69	CONC	1.20	1.10	0.50	0.50	0.50	1.00	0.50	0.50	0.50	2.20
10/09/69	CONC	0.00	0.00	0.00	1.00	1.00	1.00	0.50	0.50	2.00	0.00
10/14/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/16/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/20/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/21/69	CONC	0.50	0.50	0.50	0.00	0.50	1.00	0.50	0.50	1.20	0.50
10/23/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/27/69	CONC	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.50	2.50	0.00
10/28/69	CONC	0.50	1.90	0.50	0.00	1.50	1.30	1.60	1.20	2.80	2.00
10/29/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/03/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/04/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/10/69	CONC	1.00	1.50	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50
11/11/69	CONC	0.50	0.50	0.00	0.00	1.50	1.00	0.50	1.60	1.60	0.50
11/12/69	CCNC	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I. Potassium Concentration Mg/L

VARIABLE . . . DATE	POTASSIUM S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	W-20	W-02
07/07/69 CONC	7.80	6.80	7.20	3.50	3.70	3.80	4.30	3.30	3.70	3.60
07/08/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/09/69 CONC	4.50	4.40	4.30	5.10	4.00	4.30	4.00	4.20	4.30	3.70
07/10/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
07/11/69 CONC	4.40	4.00	4.10	4.20	3.90	3.80	3.80	4.00	3.80	3.90
07/14/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/15/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/16/69 CONC	3.90	4.50	4.10	4.10	4.90	3.90	3.80	6.10	3.80	3.90
07/17/69 CONC	4.50	4.40	4.40	5.00	4.60	4.30	4.20	4.80	3.90	4.60
07/18/69 CONC	0.00	0.00	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00
07/21/69 CONC	5.20	5.80	5.70	4.50	0.00	3.80	4.80	0.00	5.00	0.00
07/22/69 CONC	4.20	5.10	3.50	4.00	4.20	3.60	3.60	4.80	3.70	3.90
07/23/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/24/69 CONC	3.70	4.40	4.40	3.90	3.80	3.40	3.60	3.70	3.30	3.40
07/25/69 CONC	4.80	4.60	5.10	4.00	3.80	3.80	3.90	3.40	4.00	4.80
07/28/69 CONC	4.50	4.20	4.10	3.60	3.30	3.60	3.00	3.00	3.60	4.50
07/29/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/30/69 CONC	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/31/69 CONC	0.00	3.80	3.80	3.50	3.30	3.30	4.00	3.00	3.60	12.00
08/01/69 CONC	4.00	3.80	3.80	3.30	3.30	3.50	3.80	3.00	3.20	4.20
08/04/69 CONC	4.20	4.20	4.10	4.10	3.50	4.50	4.90	6.00	4.30	5.90
08/05/69 CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/06/69 CONC	3.90	3.50	3.50	4.00	4.20	4.00	4.00	4.20	3.80	6.50
08/07/69 CONC	4.20	3.60	3.50	3.60	3.80	3.80	4.40	4.50	3.50	5.40
08/08/69 CONC	3.70	3.80	3.80	3.90	5.00	4.50	5.80	5.80	4.30	8.00

Appendix I Continued

VARIABLE . . . POTASSIUM

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
08/11/69	CONC	3.90	4.10	3.70	3.30	4.10	3.90	4.70	4.20	3.30	6.20
08/12/69	CONC	4.00	4.20	3.70	3.80	4.10	4.30	4.90	4.10	3.20	6.00
08/13/69	CONC	4.00	3.60	3.50	0.00	4.70	4.70	5.20	4.20	3.30	5.80
08/14/69	CONC	4.80	4.10	0.00	3.50	5.00	4.80	6.20	4.20	3.80	6.40
08/15/69	CONC	4.60	4.10	3.70	3.70	5.00	5.10	6.20	4.60	3.40	6.00
08/18/69	CONC	4.70	3.70	3.30	4.20	5.20	5.80	5.10	4.20	3.70	6.30
08/19/69	CONC	5.10	4.50	4.50	4.80	6.20	6.00	5.60	4.60	3.40	6.30
08/20/69	CONC	0.00	4.00	3.50	0.00	5.50	5.50	6.00	4.30	5.00	5.50
08/21/69	CONC	4.00	3.80	4.00	4.10	5.60	4.70	5.10	4.00	3.10	5.20
08/22/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/25/69	CONC	4.00	3.50	3.50	2.50	2.50	2.50	2.80	2.50	3.00	5.50
08/26/69	CONC	0.00	0.00	0400	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/27/69	CONC	5.00	5.50	5.00	4.50	4.70	5.00	5.00	4.50	3.00	5.30
08/28/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/29/69	CONC	4.80	4.90	4.70	4.50	4.80	4.60	4.90	4.10	3.10	4.90
09/01/69	CONC	0.00	4.80	4.30	4.50	4.20	5.50	5.30	0.00	3.30	0.00
09/04/69	CONC	5.10	4.80	4.40	4.40	4.80	5.20	5.50	6.00	3.40	5.90
09/08/69	CONC	4.90	4.40	4.30	5.20	5.00	5.70	6.40	5.30	7.30	5.10
09/09/69	CONC	4.90	4.50	4.30	4.80	5.80	5.40	6.20	5.40	5.60	4.80
09/11/69	CONC	5.00	5.30	4.80	5.10	5.60	6.00	7.10	6.00	5.40	6.30
09/12/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69	CONC	4.90	5.80	5.40	5.90	6.60	6.90	7.40	6.20	5.20	6.10
09/16/69	CONC	6.60	6.80	6.10	5.90	6.80	6.80	7.80	0.00	5.40	6.40
09/17/69	CONC	6.00	5.20	4.00	6.00	6.30	6.30	5.10	5.60	7.20	5.60
09/18/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I Continued

VARIABLE . . . POTASSIUM DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
09/19/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/22/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/23/69	CONC	0.00	7.90	6.30	6.30	6.00	6.00	6.80	4.30	3.70	6.00
09/24/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/25/69	CONC	0.00	4.20	5.00	4.80	5.80	4.10	6.50	0.00	3.90	8.00
09/26/69	CONC	0.00	0.00	0.00	3.70	4.00	4.80	4.50	3.80	4.20	0.00
09/29/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/30/69	CONC	4.40	4.40	4.00	4.00	3.90	4.20	5.40	4.00	4.10	6.60
10/01/69	CONC	0.00	5.80	5.00	4.80	0.00	0.00	0.00	0.00	0.00	0.00
10/02/69	CONC	4.50	4.40	4.00	3.90	4.10	90.00	0.00	0.00	0.00	7.50
10/07/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/09/69	CONC	0.00	5.20	0.00	4.30	5.00	6.00	7.20	4.70	4.60	0.00
10/14/69	CONC	5.10	0.00	5.10	5.10	5.30	6.20	6.20	4.80	4.80	6.90
10/16/69	CONC	0.00	7.10	6.20	6.40	7.60	9.20	10.00	6.30	5.90	0.00
10/20/69	CONC	6.20	5.50	6.00	5.50	6.80	7.50	7.00	5.80	5.00	7.60
10/21/69	CONC	5.40	5.40	4.80	0.00	5.80	6.60	7.80	5.70	4.30	7.20
10/23/69	CONC	5.60	5.40	4.80	5.50	6.00	7.20	7.40	4.90	4.70	0.00
10/27/69	CONC	5.60	5.40	6.50	0.00	8.00	0.00	0.00	5.50	7.70	5.70
10/28/69	CONC	3.90	3.90	3.40	0.00	5.50	6.60	7.30	5.30	4.50	7.20
10/29/69	CONC	5.80	6.40	5.80	0.00	0.00	0.00	0.00	0.00	0.00	7.90
11/03/69	CONC	5.90	5.50	0.00	5.90	7.10	7.00	6.70	5.10	6.30	8.20
11/04/69	CONC	5.80	5.00	4.70	5.20	6.00	6.00	7.90	6.30	7.60	7.80
11/10/69	CONC	7.80	7.50	8.20	0.00	0.00	0.00	0.00	0.00	0.00	9.80
11/11/69	CONC	6.90	7.20	7.20	7.00	5.50	6.20	5.00	4.00	5.50	9.00
11/12/69	CONC	0.00	6.20	5.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix J. Biochemical Oxygen Demand Mg/L

VARIABLE . . . BIO OXY DEMAND										
DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
07/07/69	CONC	2.50	2.97	3.09	3.04	2.75	2.85	6.27	2.35	2.68	2.72
07/08/69	CONC	4.10	3.45	5.13	3.92	4.55	5.05	4.17	4.85	2.55	3.32
07/09/69	CONC	3.95	4.10	4.37	4.82	5.08	4.78	4.05	4.37	3.96	2.90
07/10/69	CONC	4.00	5.22	5.80	4.11	3.90	4.55	3.29	3.05	3.85	5.60
07/11/69	CONC	2.45	2.78	3.45	3.58	3.39	3.77	3.15	2.44	1.95	3.94
07/14/69	CONC	2.80	2.60	2.60	2.48	2.85	3.65	3.97	2.35	4.50	7.40
07/15/69	CONC	2.90	2.48	1.95	2.15	2.70	2.87	3.80	2.62	1.93	4.92
07/16/69	CONC	2.39	2.15	1.90	1.60	1.93	2.30	2.36	2.02	1.95	4.79
07/17/69	CONC	1.75	2.05	2.19	2.25	2.15	2.60	2.95	1.87	1.80	2.95
07/18/69	CONC	2.60	2.05	1.80	1.60	1.80	2.15	2.60	1.40	2.50	2.62
07/21/69	CONC	2.77	3.97	3.00	1.40	1.93	3.50	0.00	0.00	2.30	5.06
07/22/69	CONC	3.10	3.10	3.13	4.60	3.10	4.47	4.70	3.55	4.90	5.40
07/23/69	CONC	4.80	2.40	3.45	2.55	2.20	2.85	1.95	2.25	2.50	6.75
07/24/69	CONC	2.60	2.70	3.45	2.65	3.40	3.00	3.08	2.80	2.25	6.20
07/25/69	CONC	1.90	1.75	2.70	1.85	1.65	1.25	1.75	1.25	1.62	4.25
07/28/69	CONC	2.15	2.15	1.50	2.35	2.05	2.75	4.95	1.25	1.90	2.45
07/29/69	CONC	1.75	1.60	1.35	1.75	2.85	3.20	4.90	1.60	2.30	3.00
07/30/69	CONC	2.05	2.00	2.10	2.45	3.40	5.50	5.30	1.80	1.85	2.30
07/31/69	CONC	3.68	3.20	2.83	2.50	3.90	6.40	9.35	1.90	2.20	2.80
08/01/69	CONC	2.70	2.00	2.10	3.00	5.30	8.30		2.00	2.00	2.90
08/04/69	CONC	4.70	5.60	5.15	6.00	3.10	6.80	6.70	1.75	2.15	4.25
08/05/69	CONC	3.20	5.55	5.80	5.05	3.47	6.35	6.77	2.20	2.35	3.15
08/06/69	CONC	5.70	5.60	6.28	4.40	3.50	5.75	6.20	2.85	3.40	4.50
08/07/69	CONC	5.90	4.80	4.80	5.40	0.00	6.30	6.65	3.00	2.90	3.40
08/08/69	CONC	8.05	3.75	6.10	4.90	4.35	6.10	6.30	3.40	3.90	4.60

Appendix J Continued

VARIABLE . . . BIO OXY DEMAND

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
08/11/69	CONC	4.16	2.26	2.95	2.35	2.08	4.60	3.72	0.22	0.47	1.59
08/12/69	CONC	2.61	3.32	2.90	5.28	4.13	8.00	5.98	0.42	0.00	0.52
08/13/69	CONC	4.10	3.59	4.09	0.00	5.43	9.28	0.00	1.77	1.03	2.90
08/14/69	CONC	3.78	3.32	0.00	5.25	4.67	9.10	0.00	1.73	1.68	2.92
08/15/69	CONC	4.36	3.48	3.78	2.42	4.42	5.15	0.00	2.03	1.92	3.32
08/18/69	CONC	3.85	4.20	4.38	3.23	5.58	10.75	10.62	3.07	1.83	2.45
08/19/69	CONC	5.22	5.60	4.34	3.84	6.51	7.25	12.15	3.21	2.35	3.11
08/20/69	CONC	4.90	3.95	3.25	2.12	5.82	5.86	6.30	2.70	1.94	1.50
08/21/69	CONC	6.57	4.71	4.07	5.57	6.11	6.54	5.90	3.60	3.45	3.30
08/22/69	CONC	5.26	4.87	5.77	5.00	4.03	4.74	4.89	3.23	2.00	3.05
08/25/69	CONC	5.95	3.85	4.20	4.70	2.65	3.48	3.80	3.37	4.90	2.50
08/26/69	CONC	4.18	3.95	5.43	2.98	3.12	3.30	4.70	2.00	0.00	0.00
08/27/69	CONC	5.08	5.10	4.42	4.62	3.08	4.00	4.48	2.08	0.00	0.00
08/28/69	CONC	5.75	6.10	5.45	6.20	4.20	6.55	7.50	4.60	1.92	0.00
08/29/69	CONC	7.70	7.05	8.80	5.02	5.30	7.28	76.40	3.90	3.65	2.48
09/01/69	CONC	0.00	3.88	5.95	6.20	6.20	6.20	76.20	3.85	0.00	0.00
09/04/69	CONC	0.00	0.00	0.00	5.00	4.50	7.60	75.35	3.42	3.02	0.00
09/08/69	CONC	2.00	0.00	0.00	2.60	2.52	4.90	3.98	1.58	2.82	1.45
09/09/69	CONC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/11/69	CONC	3.85	1.38	1.90	1.66	1.30	2.04	2.98	1.33	1.32	1.11
09/12/69	CONC	0.00	2.68	2.15	3.02	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69	CONC	4.50	5.12	0.00	5.30	4.70	8.28	78.67	2.35	2.10	2.28
09/16/69	CONC	7.50	0.00	7.30	3.90	4.59	0.90	7.04	0.00	2.10	1.90
09/17/69	CONC	6.85	7.00	6.46	4.55	4.82	6.76	6.05	7.87	0.00	1.35
09/18/69	CONC	6.09	3.32	3.85	2.66	2.59	3.90	2.40	4.25	3.00	2.36

Appendix J Continued

VARIABLE . . . BIO OXY DEMAND DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	H-20	W-02
09/19/69										
CONC	0.00	2.64	3.15	2.22	0.00	0.00	0.00	0.00	0.00	0.00
09/22/69										
CONC	3.40	2.23	2.75	1.86	2.25	2.35	2.96	1.82	1.75	1.90
09/23/69										
CONC	0.00	2.78	2.05	0.93	0.00	1.05	5.40	1.49	0.15	2.10
09/24/69										
CONC	2.02	3.93	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/25/69										
CONC	6.01	6.60	6.74	1.76	2.08	2.70	2.90	6.40	6.40	6.18
09/26/69										
CONC	0.00	0.00	0.00	1.05	1.57	3.06	4.30	1.07	1.64	0.00
09/29/69										
CONC	7.95	1.53	1.29	7.98	2.50	7.95	8.48	1.30	1.25	1.62
09/30/69										
CONC	2.00	2.97	1.66	2.05	3.35	6.30	6.34	7.80	2.02	1.32
10/01/69										
CONC	0.00	2.40	2.80	4.40	0.00	0.00	0.00	0.00	0.00	0.00
10/02/69										
CONC	0.00	0.00	4.07	0.00	0.00	0.00	0.00	0.00	0.00	2.12
10/07/69										
CONC	3.65	3.42	1.72	2.60	2.02	4.94	2.72	0.00	0.00	0.00
10/09/69										
CONC	0.00	7.22	0.00	5.20	4.60	7.45	8.16	4.94	3.90	0.00
10/14/69										
CONC	5.33	0.00	7.40	3.30	4.13	5.35	6.40	2.60	3.85	3.13
10/16/69										
CONC	0.00	6.80	6.85	3.25	3.00	3.05	5.87	5.05	2.32	0.00
10/20/69										
CONC	4.05	5.51	4.60	4.80	3.25	5.40	5.28	0.00	0.00	2.01
10/21/69										
CONC	6.10	6.95	2.50	0.00	4.28	5.97	3.62	3.25	3.18	5.30
10/23/69										
CONC	2.20	2.02	1.83	4.90	2.70	5.18	0.00	2.60	0.00	0.00
10/27/69										
CONC	8.10	3.78	4.40	0.00	3.68	0.00	0.00	2.50	2.51	2.80
10/28/69										
CONC	3.30	1.85	2.70	0.00	2.80	3.50	6.05	0.00	0.00	0.00
10/29/69										
CONC	1.58	3.25	4.65	0.00	0.00	0.00	0.00	0.00	0.00	4.20
11/03/69										
CONC	4.90	8.30	0.00	6.10	0.00	4.50	5.28	0.00	5.60	3.02
11/04/69										
CONC	3.60	3.80	2.50	3.70	4.40	2.68	6.55	0.00	3.55	0.00
11/10/69										
CONC	4.21	0.00	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/11/69										
CONC	3.43	0.00	3.85	3.44	3.40	2.52	5.16	2.18	2.48	0.00
11/12/69										
CONC	0.00	2.00	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix K. Dissolved Oxygen Concentration Mg/L

VARIABLE . . . DISSOLVED OXYGEN DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-28	W-20	W-82
07/07/69										
CONC	6.60	7.68	7.62	6.98	6.30	5.72	6.40	6.32	6.42	6.88
07/08/69										
CONC	7.10	7.98	7.85	7.02	6.82	6.72	6.70	6.70	7.12	7.70
07/09/69										
CONC	7.10	7.80	7.80	7.02	6.90	6.92	7.10	6.62	7.10	6.82
07/10/69										
CONC	7.40	8.02	8.02	7.50	6.90	6.90	7.02	6.58	7.20	7.32
07/11/69										
CONC	6.90	6.82	7.80	6.95	6.68	6.40	6.65	6.55	7.10	6.70
07/14/69										
CONC	6.38	7.22	7.10	6.68	6.38	6.25	6.23	6.10	6.95	8.45
07/15/69										
CONC	6.45	7.30	7.30	6.60	6.30	6.02	6.48	6.00	6.90	5.30
07/16/69										
CONC	6.40	7.08	6.98	6.20	5.98	5.62	5.80	5.70	6.40	6.50
07/17/69										
CONC	6.20	6.80	6.70	5.90	5.62	5.30	5.40	5.60	6.20	4.30
07/18/69										
CONC	6.40	6.98	6.90	5.90	5.75	5.60	5.55	5.60	6.40	6.10
07/21/69										
CONC	6.30	7.12	7.10	5.98	6.10	6.20	0.00	0.00	6.40	6.98
07/22/69										
CONC	6.80	7.52	7.52	6.40	5.80	6.40	6.75	5.00	7.00	5.00
07/23/69										
CONC	6.20	6.85	6.70	5.80	5.20	5.90	6.10	4.75	6.30	7.00
07/24/69										
CONC	6.25	5.98	6.85	5.90	5.50	5.62	5.95	5.15	6.40	4.05
07/25/69										
CONC	6.50	7.32	7.10	6.20	6.30	6.02	6.25	6.10	6.75	5.70
07/28/69										
CONC	6.98	7.70	7.35	6.68	6.70	6.48	6.85	6.68	7.20	5.85
07/29/69										
CONC	6.70	7.50	6.98	6.05	6.38	6.28	6.32	5.90	6.65	6.20
07/30/69										
CONC	7.20	7.75	7.15	6.58	7.75	8.90	8.28	6.65	7.55	6.18
07/31/69										
CONC	7.72	8.50	7.70	6.20	7.60	8.90	6.72	6.35	6.85	6.82
08/01/69										
CONC	7.25	7.75	7.05	7.28	8.85	11.00	0.00	6.90	7.20	5.55
08/04/69										
CONC	9.60	10.60	11.20	8.05	6.85	7.62	6.72	6.70	7.10	7.52
08/05/69										
CONC	8.15	6.98	7.30	9.42	6.68	7.20	7.98	6.15	6.98	6.45
08/06/69										
CONC	10.60	9.60	9.28	7.80	6.25	6.98	4.78	6.12	6.70	7.85
08/07/69										
CONC	7.70	6.50	6.50	8.65	6.40	6.98	5.62	6.15	6.90	5.90
08/08/69										
CONC	8.88	9.02	6.90	6.50	5.58	6.02	3.98	5.58	5.88	7.70

Appendix K Continued

VARIABLE . . . DISSOLVED OXYGEN

DATE	S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	N-20	W-02
08/11/69										
CONC	8.35	9.80	6.50	5.30	6.05	6.65	4.58	5.80	6.62	9.20
08/12/69										
CONC	7.18	6.80	6.40	6.00	7.00	7.85	7.88	6.90	7.35	6.25
08/13/69										
CONC	8.15	9.75	7.35	0.00	6.75	8.85	6.60	6.10	6.50	9.52
08/14/69										
CONC	7.15	6.50	0.00	6.20	7.10	8.55	0.20	6.50	7.10	6.30
08/15/69										
CONC	8.90	9.88	8.40	5.75	5.60	5.85	3.80	5.80	6.00	8.35
08/18/69										
CONC	6.70	5.80	5.80	5.10	5.20	5.40	3.20	5.90	6.40	5.56
08/19/69										
CONC	7.95	7.25	6.60	4.40	5.70	7.10	2.20	5.05	5.40	6.90
08/20/69										
CONC	7.38	6.30	6.10	4.80	4.90	4.70	5.30	6.45	6.60	6.15
08/21/69										
CONC	9.00	8.20	7.95	6.85	5.85	6.05	0.00	6.70	7.80	8.00
08/22/69										
CONC	7.65	7.20	7.35	6.20	6.18	5.65	6.00	6.10	7.00	5.40
08/25/69										
CONC	8.80	7.40	8.00	5.70	5.70	5.40	4.60	6.00	5.90	6.65
08/26/69										
CONC	7.10	6.35	6.80	6.10	6.15	5.90	5.65	6.00	6.05	5.25
08/27/69										
CONC	5.60	9.85	8.90	5.85	6.20	6.80	4.70	5.60	6.45	7.40
08/28/69										
CONC	7.40	6.50	8.05	7.60	7.00	8.10	7.00	7.00	6.30	5.70
08/29/69										
CONC	10.20	9.02	9.80	6.40	6.60	8.45	0.00	5.60	5.80	7.50
09/01/69										
CONC	0.00	10.50	7.90	6.85	5.90	6.50	0.00	5.90	7.20	0.00
09/04/69										
CONC	9.70	11.20	7.40	5.60	6.40	6.70	0.00	5.50	5.95	10.80
09/08/69										
CONC	7.25	7.25	6.60	6.34	6.35	6.10	4.75	5.60	6.40	6.50
09/09/69										
CONC	7.20	8.80	7.80	5.50	6.70	6.10	5.00	6.55	7.45	7.80
09/11/69										
CONC	8.10	8.30	7.90	6.60	7.20	7.50	5.45	6.80	7.70	8.30
09/12/69										
CONC	0.00	11.40	7.29	9.95	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69										
CONC	7.20	6.90	8.60	7.60	6.95	8.10	0.00	6.55	6.40	6.60
09/16/69										
CONC	7.30	6.30	9.20	6.40	6.40	6.67	5.40	0.00	6.10	5.70
09/17/69										
CONC	7.00	6.90	7.20	4.60	6.80	5.90	5.70	7.00	6.80	6.85
09/18/69										
CONC	7.10	7.60	6.60	7.03	6.30	5.70	6.52	6.30	7.00	7.40

Appendix K Continued

VARIABLE . . . DISSOLVED OXYGEN

DATE		S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
09/19/69	CONC	0.00	0.00	8.10	7.35	0.00	0.00	0.00	0.00	0.00	0.00
09/22/69	CONC	7.50	8.10	8.10	7.10	7.20	6.55	6.65	6.25	7.75	7.10
09/23/69	CONC	0.00	8.00	7.70	6.80	7.00	6.40	5.30	7.00	7.30	0.00
09/24/69	CONC	7.20	7.60	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/25/69	CONC	8.30	8.30	8.10	7.10	7.20	6.50	5.40	6.90	8.20	7.70
09/26/69	CONC	0.00	0.00	0.00	7.40	7.85	7.60	8.10	7.20	7.75	0.00
09/29/69	CONC	9.10	8.80	8.70	9.10	10.20	11.80	9.85	9.10	8.70	8.30
09/30/69	CONC	8.70	8.70	8.20	8.90	9.80	12.00	8.90	7.90	8.70	7.30
10/01/69	CONC	0.00	8.75	9.00	9.10	0.00	0.00	0.00	0.00	0.00	0.00
10/02/69	CONC	8.00	8.00	7.90	8.40	7.60	10.20	0.00	0.00	0.00	6.70
10/07/69	CONC	7.30	8.10	8.30	8.30	7.30	7.60	6.70	6.90	7.60	6.40
10/09/69	CONC	0.00	7.30	0.00	0.00	0.00	0.00	8.50	0.00	8.30	0.00
10/14/69	CONC	7.20	0.00	7.40	6.40	5.20	4.60	5.00	6.00	5.90	5.40
10/16/69	CONC	0.00	8.20	8.10	8.40	6.90	6.50	4.90	6.50	8.20	0.00
10/20/69	CONC	9.00	8.80	9.20	8.90	8.00	8.00	6.50	8.00	7.80	7.80
10/21/69	CONC	9.40	8.80	9.20	0.00	8.60	8.70	4.40	8.50	0.00	7.70
10/23/69	CONC	11.50	11.80	12.00	11.00	9.80	9.30	7.60	10.10	10.50	10.00
10/27/69	CONC	10.60	10.50	8.90	0.00	8.70	0.00	0.00	9.30	9.20	10.20
10/28/69	CONC	11.40	11.30	11.30	0.00	9.80	9.00	9.00	10.50	11.00	10.10
10/29/69	CONC	12.20	11.70	12.80	0.00	0.00	0.00	0.00	0.00	0.00	11.50
11/03/69	CONC	7.60	7.90	0.00	9.20	7.10	6.30	5.60	7.70	9.60	6.30
11/04/69	CONC	10.40	10.40	10.80	10.90	9.20	9.10	9.00	9.20	9.90	8.80
11/10/69	CONC	10.10	9.90	9.70	0.00	0.00	0.00	0.00	0.00	0.00	8.70
11/11/69	CONC	10.40	10.20	10.50	10.10	9.90	9.70	9.30	10.30	10.20	9.30
11/12/69	CONC	0.00	9.90	9.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix L. Stage In Feet and Hundredths of Feet

VARIABLE . . . DATE	STAGE S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	M-20	W-02
07/07/69 CONC	2.70	0.00	0.00	2.75	0.00	0.00	2.77	2.40	4.93	0.00
07/08/69 CONC	2.51	0.00	0.00	6.31	0.00	0.00	4.08	4.60	4.09	0.00
07/09/69 CONC	3.34	0.00	0.00	6.28	0.00	0.00	3.18	4.84	3.55	0.00
07/10/69 CONC	2.95	0.00	0.00	6.96	0.00	0.00	2.50	4.30	3.13	0.00
07/11/69 CONC	2.62	0.00	0.00	4.26	0.00	0.00	2.10	3.30	2.75	0.00
07/14/69 CONC	2.37	0.00	0.00	4.52	0.00	0.00	2.44	3.70	3.29	0.00
07/15/69 CONC	2.27	0.00	0.00	4.08	0.00	0.00	2.00	3.30	2.65	0.00
07/16/69 CONC	1.96	0.00	0.00	3.40	0.00	0.00	1.83	2.88	2.37	0.00
07/17/69 CONC	1.74	0.00	0.00	2.96	0.00	0.00	1.68	2.64	2.20	0.00
07/18/69 CONC	1.53	0.00	0.00	2.74	0.00	0.00	1.58	2.46	2.40	0.00
07/21/69 CONC	0.00	0.00	0.00	3.05	0.00	0.00	0.00	0.00	4.30	0.00
07/22/69 CONC	2.78	0.00	0.00	6.05	0.00	0.00	3.20	5.75	3.59	0.00
07/23/69 CONC	3.09	0.00	0.00	6.96	0.00	0.00	2.36	5.72	3.13	0.00
07/24/69 CONC	3.00	0.00	0.00	5.48	0.00	0.00	1.99	3.70	2.75	0.00
07/25/69 CONC	2.12	0.00	0.00	3.68	0.00	0.00	1.80	3.18	2.44	0.00
07/28/69 CONC	1.43	0.00	0.00	2.60	0.00	0.00	1.52	2.56	2.08	0.00
07/29/69 CONC	1.37	0.00	0.00	2.53	0.00	0.00	1.61	2.47	2.05	24.14
07/30/69 CONC	1.33	0.00	0.00	2.48	0.00	0.00	1.49	2.57	2.04	24.20
07/31/69 CONC	1.30	0.00	0.00	2.49	0.00	0.00	1.45	2.45	1.92	24.23
08/01/69 CONC	1.31	0.00	0.00	2.39	0.00	0.00	0.00	2.35	1.89	24.28
08/04/69 CONC	1.34	0.00	0.00	2.24	0.00	0.00	1.32	2.97	1.84	24.16
08/05/69 CONC	1.26	0.00	0.00	2.55	28.19	30.09	1.30	2.64	1.83	24.33
08/06/69 CONC	1.34	0.00	28.50	2.36	28.55	30.15	1.24	2.44	1.79	23.95
08/07/69 CONC	1.24	22.40	29.59	2.20	30.18	30.18	1.23	2.27	1.75	24.38
08/08/69 CONC	1.19	22.50	29.69	2.13	28.85	30.20	1.21	2.21	1.72	24.49

Appendix L Continued

VARIABLE . . . DATE	STAGE S-10	S-20	S-22	S-26	S-38	S-40	S-52	T-20	[illegible]	[illegible]
08/11/69 CONC	1.10	22.66	29.72	2.07	28.97	30.14	1.43	2.11	1.69	24.63
08/12/69 CONC	1.11	22.59	29.74	2.08	28.85	30.55	1.27	2.12	1.68	24.68
08/13/69 CONC	1.11	22.59	29.73	0.00	28.95	30.29	1.28	2.10	1.68	24.71
08/14/69 CONC	1.11	22.61	0.00	2.03	28.94	30.16	1.23	2.10	1.67	24.62
08/15/69 CONC	1.07	22.62	29.80	2.04	28.97	30.25	1.20	2.00	1.62	24.67
08/18/69 CONC	1.14	22.54	29.75	2.06	28.81	29.82	1.44	2.05	1.65	24.56
08/19/69 CONC	1.13	22.56	29.75	2.14	28.81	30.02	1.34	2.06	1.70	24.58
08/20/69 CONC	1.14	22.55	29.79	2.15	26.41	26.76	2.60	2.12	1.68	24.60
08/21/69 CONC	1.33	21.79	28.96	3.57	25.05	25.84	0.00	2.48	1.65	24.11
08/22/69 CONC	1.90	21.65	28.89	3.38	26.98	28.37	1.88	2.72	1.61	23.28
08/25/69 CONC	1.27	21.61	29.38	2.32	28.64	29.84	1.40	2.19	1.58	24.36
08/26/69 CONC	1.27	22.49	29.73	2.15	28.85	30.02	1.33	2.12	1.55	24.50
08/27/69 CONC	1.11	22.65	29.81	2.07	28.91	30.13	1.28	2.06	1.52	24.62
08/28/69 CONC	1.10	22.66	29.83	0.00	29.00	30.30	1.25	2.00	1.55	24.66
08/29/69 CONC	1.08	22.68	29.90	2.00	29.11	30.27	0.00	2.03	1.54	24.71
09/01/69 CONC	0.00	22.73	29.92	1.94	29.16	30.38	0.00	2.03	1.55	0.00
09/04/69 CONC	0.00	22.67	29.80	2.19	27.49	30.28	0.00	3.23	1.56	24.78
09/08/69 CONC	1.23	0.00	29.20	2.60	0.00	29.78	1.47	2.21	2.51	24.18
09/09/69 CONC	1.40	22.19	29.46	2.35	28.13	29.84	1.39	3.04	2.10	24.13
09/11/69 CONC	1.36	22.20	29.46	2.56	28.24	30.20	1.23	2.63	1.72	24.13
09/12/69 CONC	0.00	0.00	29.54	2.32	0.00	0.00	0.00	0.00	0.00	0.00
09/15/69 CONC	1.13	22.60	29.89	0.00	32.07	30.43	0.00	0.00	0.00	24.65
09/16/69 CONC	1.12	22.65	0.00	1.97	29.10	30.47	1.15	0.00	1.50	24.67
09/17/69 CONC	1.23	0.00	29.20	2.54	0.00	29.82	1.18	2.48	2.28	24.45
09/18/69 CONC	1.90	21.16	28.25	3.94	25.98	27.02	2.11	4.12	4.01	23.15

Appendix L Continued

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VARIABLE . . . STAGE
 DATE           S-10      S-20      S-22      S-26      S-38      S-40      S-52      T-20      H-20      W-02

09/19/69
      CONC      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/22/69
      CONC      1.75      0.00      0.00      2.95      0.00      0.00      1.46      2.83      2.06      0.00
09/23/69
      CONC      0.00     22.07     29.35      2.64     28.11     29.86      1.37      2.62      1.98      0.00
09/24/69
      CONC      1.45      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
09/25/69
      CONC      0.00     22.00     29.22      2.81     27.95     29.83      1.41      2.50      2.43     23.95
09/26/69
      CONC      0.00      0.00      0.00      2.58      0.00     30.67      1.43      2.65      2.23      0.00
09/29/69
      CONC      1.34     22.07     29.36      2.56      0.00     30.85      1.40      2.52      2.24     24.06
09/30/69
      CONC      0.00      0.00     29.45      2.44     28.36     29.98      1.39      2.44      2.08     24.10
10/01/69
      CONC      0.00      0.00     30.40      2.39      0.00      0.00      0.00      0.00      0.00      0.00
10/02/69
      CONC      1.31      0.00      0.00      2.25     28.35     30.14      0.00      0.00      0.00      0.00
10/07/69
      CONC      1.80      0.00      0.00      2.28     28.59     29.99      1.31      2.28      1.82      0.00
10/09/69
      CONC      0.00      0.00      0.00      2.21     28.82     30.21      1.24      2.16      1.78      0.00
10/14/69
      CONC      0.00      0.00      0.00      2.12     28.96     30.32      1.20      2.17      1.73      0.00
10/16/69
      CONC      0.00      0.00      0.00      2.10     28.91     30.29      1.28      2.20      1.72      0.00
10/20/69
      CONC      0.00     22.58     29.85      2.10      0.00     30.18      1.27      2.15      1.12      0.00
10/21/69
      CONC      0.00      0.00      0.00      0.00     28.89     30.36      1.26      2.17      1.84      0.00
10/23/69
      CONC      0.00      0.00      0.00      2.09     28.98     30.28      1.31      2.15      1.73      0.00
10/27/69
      CONC      0.00      0.00     29.89      0.00      0.00      0.00      0.00      2.13      1.76     24.61
10/28/69
      CONC      0.00     22.62     29.80      0.00     29.02     30.25      1.23      2.14      1.75     24.61
10/29/69
      CONC      1.08      0.00     29.81      0.00      0.00      0.00      0.00      0.00      0.00     24.62
11/03/69
      CONC      1.18      0.00      0.00      0.00      0.00     29.80      0.00      0.00      0.00     24.45
11/04/69
      CONC      1.22      0.00     29.43      2.75     26.89     28.14      2.02      2.95      2.33      0.00
11/10/69
      CONC      1.42      0.00     29.39      0.00      0.00      0.00      0.00      0.00      0.00     24.07
11/11/69
      CONC      1.25      0.00     29.52      2.47     28.31     29.73      1.45      2.95      1.96      0.00
11/12/69
      CONC      0.00      0.00     29.49      0.00      0.00      0.00      0.00      0.00      0.00      0.00
```

1 *Accession Number*	**2** *Subject Field & Group* 05G	**SELECTED WATER RESOURCES ABSTRACTS** **INPUT TRANSACTION FORM**

5 *Organization*

Heidelberg College

6 *Title*

Water Quality Control Through Flow Augmentation

10 *Author(s)*

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16 *Project Designation* 16080DF001/71

21 *Note*

22 *Citation*

23 *Descriptors (Starred First)*

Water quality,* Water analysis,* Flow augmentation,* Water management,* Reservoirs, Nutrients, River flow, Water pollution sources

25 *Identifiers (Starred First)*

Sandusky River,* North Central Ohio

27 *Abstract*

To evaluate effects of augmentation from upground reservoirs on water quality, studies of the relationship between water quality and river flow were undertaken in a sixty mile section of the Sandusky River in North Central Ohio.

As river flow decreased from near-flood conditions to low flow conditions, the concentrations of calcium, magnesium, sodium and fluoride increased. In contrast, for most river sections, concentrations of total phosphorus and soluble orthophosphorus increased as flow volume increased (probably due to agricultural surface runoff). Immediately downstream from sewage treatment plants, orthophosphorus concentrations did increase with decreasing flow. During most of the study period the total phosphorus flux at the downstream station was much less than the total upstream input from sewage treatment plants. Nitrate and potassium concentrations were variable and showed no correlation with flow.

Oxygen concentrations were near saturation at medium and high flows but varied widely above and below saturation at low flows. In most river sections, algal respiration rather than B.O.D. was responsible for low D.O. It is predicted that flow augmentation will significantly reduce algal growth in the stream, with increased flow velocity being more important than dilution of algal nutrients. (Baker-Heidelberg)

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